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CONTENTS

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Functional response of a reduviid predator *Acanthaspis pedestris* Stål (Hemiptera: Reduviidae) to three lepidopteran insect pests

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ABSTRACT: Functional responses of *Acanthaspis pedestris* Stål to three lepidopteran pests viz., *Spodoptera litura* (Fabricius), *Helicoverpa armigera* (Hübner) and *Achaea janata* (Linnaeus) larvae were studied in the caged cotton branches. Both adult males and females of *A. pedestris* responded to the increasing prey density of *S. litura, H. armigera* and *A. janata* by killing more number of prey than at lower prey densites, thus exhibiting type II functional response. The searching capacity of *A. pedestris* increased with the increasing prey density and this reflected the predator's biocontrol potential.

KEYWORDS: Functional response, reduviidae, *Acanthaspis pedestris*, *Spodoptera litura*, *Helicoverpa armigera*, *Achaea janata*

INTRODUCTION

Two characteristics of natural enemies, their functional and numerical responses to variation in prey density, are thought to be central for successful suppression of pest populations. The functional response refers to the change in the number of prey consumed per unit time in relation to prey density (Solomon, 1949; Hassell, 1978).

Functional response comprises population biology, evolutionary biology, ethology and physiology. Because it links together different trophic levels in population biology, determines energy intake and mortality risk in evolutionary biology, influences adaptive animal behaviour by energy intake or mortality risk and short- as well as long- term physiological responses of individuals (Jeschke *et al.*, 2004).

When the number of host predated per unit time is plotted against the number of host available per predator, any one of the following four types of functional responses can occur. (i) an increasing linear relationship (Type I), (ii) a decelerating relationship (Type II), (iii) sigmoid relationship (Type III) and (iv) dome-shaped

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relationship (Type IV) (Holling, 1959a; Hassell, 1978; Luck, 1985). These functional response curves can be used to infer basic mechanisms underlying the interactions of predator–prey behaviour, to clarify coevolutionary relationship and to enhance practical predictive powers for biological control. The knowledge of functional response is therefore essential for a clear understanding and approach to modeling predator–prey interaction (O'Neil and Stimac, 1988). Although the dynamics of predator–prey relationship are generally complex, the functional response of predator or the relationship between the number of prey consumed by the predator and prey density is almost common (Holling, 1959b).

The reduviids are polyphagous and they attack a greater number of prey at higher prey density than it could do at lower prey density (Ambrose, 1999, 2000, 2003; Claver and Ambrose, 2002; Claver *et al.*, 2003). Among them *Acanthaspis pedestris* Stål is a potential polyphagous predator suppressing the population of lepidopteran pests (Ambrose, 2003; Claver *et al.*, 2003).

To quantify the pest suppression efficacy of this reduviid predator, we assessed its functional response to pest density of three lepidopteran larvae viz., *Spodoptera litura* (Fabricius), *Helicoverpa armigera* (Hübner) and *Achaea janata* (Linnaeus).

MATERIALS AND METHODS

The adults of *Acanthaspis pedestris* Stål were collected from Muppandal scrub jungles of Mahendragiri Hills of Kanyakumari District, Tamil Nadu, South India (altitude 60 ± 6.43 m; latitude 77°31′ E and 8°22′ N) and reared in the laboratory under optimal conditions (temperature 30 ± 2°C; relative humidity 75 ± 5%; photoperiod 12 ± 1 h) on flour moth larvae *Corcyra cephalonica* (Stainton). The newly moulted and 48 h starved adults of *A. pedestris* were used for functional response experiments.

The experiments were conducted in Entomology Research Unit Experimental Station at St. Xavier's College Campus. The entire cotton flowering plants were covered with small nylon mesh cages supported with iron frame (75 cm diameter $\times 150$ cm height). Before covering, the plant was shaken to exclude insects, spiders, etc., if any. Then a laboratory reared and prey deprived *A. pedestris* and freshly laboratory reared fourth instar larvae of *S. litura, H. armigera* and *A. janata* at five different densities such as 1, 2, 4, 8 and 16 prey per predator were introduced into experimental cages, separately. Thus, three different prey at five different densities were maintained separately for five days. Five replicates were maintained for each category. The number of prey consumed or killed was monitored and the prey number was maintained constant by replacing prey consumed or killed with fresh prey throughout the experimental period.

In the present study 'disc' equation of Holling (1959a) was used to describe the functional response of *A. pedestris*. The various parameters in the 'disc' equation are, x = prey density, y = total number of prey killed in a given period of time, y/x = the attack ratio, T_t = total time in days when prey was exposed to the predator, b = time spent for handling each prey by the predator (T_t/k) and a = rate of discovery per unit of searching time $[(y/x)/T_s]$.

The parameters b and a were directly measured in the present study. The handling time b was estimated as the time spent for pursuing, subduing, feeding and digesting each prey. The maximum prey consumption was represented by k value and it was restricted to the higher prey density that no searching is required. Another parameter a the rate of discovery was defined as the proportion of the prey attacked successfully by the predator per unit of searching time. Discovery was instantaneous, with little searching time being required. Although the parameter rate of discovery (a) was theoretically infinite, the predator did spent some time in searching for the prey at lower prey density. The extent of searching was clearly related to the degree of satiation (Holling, 1959a).

Assuming that predation is proportional to the prey density and to the time spent by the predator in searching prey (T_s), the expression of relationship is:

$$Y = aT_s x. \tag{1}$$

But the time available for searching is not constant. It is reduced from the total time (T_t) by the time spent for handling the prey. If one presumes that each prey requires, a constant amount of time b for the consumption, then,

$$T_s = T_t - by. \tag{2}$$

Substituting (2) in (1), Holling's 'disc' equation is

$$Y = a(T_t - by)x \tag{3}$$

(or)

$$Y = (T_t ax)/(1 + abx).$$

(Holling, 1959a).

The regression analysis was made to determine the relationship between the prey density and the number of prey consumed, searching time, attack ratio and handling time (Gomez and Gomez, 1984).

RESULTS

Predation by *A. pedestris* on different densities of three lepidopteran prey yielded a curvilinear Type II functional response (Holling, 1959a) (Tables 1–3). Most predators consumed all or most prey provided at lower prey densities and showed a deceleration in rate of predation with greater variation at higher prey densities. This was further confirmed by the positive correlation obtained between the prey density and the prey killed ($y = 3.265 + 0.172x$; $r = 0.881$, $y = 2.476 + 0.159x$, $r = 0.742$ for the female and male predators to *S. litura* larvae, $y = 3.208 + 0.150x$, $r = 0.787$; $y = 3.183 + 0.0995x$, $r = 0.562$ for the female and male predators to *H. armigera* larvae, $y = 3.254 + 0.133x$, $r = 0.878$; $y = 3.146 + 0.073x$, $r = 0.594$ for the female and male predators to *A. janata* larvae respectively).

The maximum predation represented by k value was always found restricted to high prey density ($k = 5.60$ and 4.83 for adult female and male predators of *S. litura*

TABLE 1. Cumulative functional response of *Acanthaspis pedestris* to *Spodoptera litura* larvae

Sex	Prey density (x)	Prey attacked (y)	Max'y (k)	Days/y $b = T_t/k$	All y's days (by)	Searching days $T_s = T_t - by$	Attack ratio y/x	Rate of discovery $(y/x)/T_s = (a)$	Disc equation $Y = a(T_t - y)x$
	1	2.67			2.38	2.62	2.67	1.02	
	2	3.67			3.28	1.72	1.84	1.07	
Female	4	4.50	5.60	0.89	4.01	0.99	1.13	1.14	$Y = 0.65(5 - 0.89y)x$
	8	5.16			4.61	0.39	0.65	1.67	
	16	5.67			4.98	0.02	0.35	–	
								Mean = 0.65	
	1	2.16			2.24	2.76	2.14	0.78	
	2	2.83			2.93	2.07	1.42	1.46	
Male	4	3.50	4.83	1.04	3.62	1.38	0.88	0.64	$Y = 0.95(5 - 1.04y)x$
	8	4.00			4.04	0.96	0.49	0.51	
	16	4.83			4.99	–	0.30	–	
								Mean = 0.95	

TABLE 2. Cumulative functional response of *Acanthaspis pedestris* to *Helicoverpa armigera* larvae

Sex	Prey density (x)	Prey attacked (y)	Max'y (k)	Days/y $b = T_t/k$	All y's days (by)	Searching days $T_s = T_t - by$	Attack ratio y/x	Rate of discovery $(y/x)/T_s = (a)$	Disc equation $y = a(Tt - by)x$
	1	2.3			2.21	2.79	2.3	0.82	
Female	2	3.8			3.65	1.35	1.9	1.41	
	4	4.4	5.2	0.96	4.22	0.78	1.1	1.41	$Y = 2.48(5 - 0.96y)x$
	8	5.0			4.80	0.20	0.63	3.15	
	16	5.2			4.90	0.10	0.33	3.3	
								Mean = 2.48	
	1	2.2			2.29	2.21	2.2	0.81	
Male	2	3.2			3.33	1.67	1.6	0.96	
	4	4.8	4.8	1.04	4.99	0.01	1.2	–	$Y = 0.72(5 - 1.04y)x$
	8	4.5			4.68	0.32	0.56	0.24	
	16	4.3			4.47	0.53	0.27	0.51	
								Mean = 0.72	

TABLE 3. Cumulative functional response of *Acanthaspis pedestris* to *Achaea janata* larvae

Sex	Prey density (x)	Prey attacked (y)	Max'y (k)	Days/y $b = T_t/k$	All y's days (by)	Searching days $T_s = T_t - by$	Attack ratio y/x	Rate of discovery $(y/x)/T_s = (a)$	Disc equation $Y = a(Tt - by)x$
	1	2.7			2.59	2.41	2.70	1.12	
	2	3.8			3.65	1.35	1.90	1.41	
Female	4	4.2	5.2	0.962	4.03	0.97	1.05	1.08	$Y = 0.59(5 - 1.096y)x$
	8	4.5			4.32	0.68	0.56	0.82	
	16	5.2			4.99	0.01	0.33	–	
								Mean = 0.59	
	1	2.3			2.74	2.26	2.3	1.02	
	2	3.7			4.40	0.60	1.85	3.08	
Male	4	3.8	4.2	1.190	4.52	0.48	0.95	1.98	$Y = 2.06(5 - 1.19y)x$
	8	4.2			4.98	0.02	0.53	–	
	16	4.0			4.76	0.24	0.25	1.04	
								Mean = 2.06	

$k = 5.2$ and 4.8 for adult female and male predators of *H. armigera* larvae, $k = 5.2$ and 4.2 for adult female and male predators of *A. janata* larvae).

The searching time decreased as the prey density was increased. Uniformly negative correlations were obtained between the prey densities and the searching times of the predator at all prey densities ($y = 2.07 - 0.1487x$; $r = -0.868$, $y = 2.677 - 2.361x$; $r = -0.924$ for the female and male predators of *S. litura*, $y = 1.900x - 0.138x$; $r = -0.768$; $y = 1.688 - 0.103x$; $r = -0.562$ for the female and male predators of *H. armigera* larvae and $y = 1.876 - 0.128x$; $r = -0.877$, $y = 1.259 - 0.087x$; $r = -0.596$ for the female and male predators of *A. janata* larvae respectively). Uniformly, the female predators were more vigorous in responding to the increasing prey density.

DISCUSSION

Functional response divulges that prey consumption by a predator increased with increase in prey density, whereas per cent prey consumption decreased, which exemplifies Holling's Type II predatory response (1959a). Type II functional response is typical of most heteropteran predators (Cohen and Tong, 1997; Cohen, 2000). Similarly, present findings are in close agreement to those recorded for other reduviids (Ambrose and Claver, 1997; Claver and Ambrose, 2002; Claver *et al.*, 2003) and predatory coccinellid beetles (Omkar and James, 2001; Omkar and Srivastava, 2001). Hunger and time spent by the predator in searching and handling prey (pursuing, subduing and consuming the prey and then preparing itself for further search) affect the prey consumption (Houck, 1991).

Increased prey consumption at higher prey density might be due to different phenomena operating simultaneously in a predatory arena. Firstly, it results due to decrease in searching time because the probability of contacts between the prey and predator increases at higher prey density, which results in increased prey consumption. Secondly, predator stays in an arena where prey aggregates and continues to feed until satiation or even beyond (Williams and Juliano, 1985; Claver and Ambrose, 2002). Handling time depends upon factors such as speed of pursuit of predator and prey escape or prey capture success (Akhtaruzzaman and Ahmad, 1998). The inversely proportional relationship found between the attack rate and prey level was similar to the observations of Claver and Ambrose (2002); Claver *et al.* (2003). It is presumed that the predator required lesser time to search the prey and it spent more time on nonsearching activities at higher prey densities, which in turn might have caused perceptive decline in the attack rate until hunger was established. This releases the trade-off situations at higher prey densities and closes the gap between optimal foraging and satiating theory (Jeschke *et al.*, 2002). Moreover, higher prey density also results in reduction of unsuccessful attacks of predator on a prey, as there are less chances of escape when compared to those in scarce prey density, where there are more chances for the prey to escape from the predator (O'Neil, 1988).

At high prey density, less time was spent in searching; therefore more time was spent in handling, whereas at low prey density the searching time always dominated

the handling time (O'Neil, 1988). Disturbance by another prey at higher prey densities also aggravated a hungry predator during feeding, which resulted in killing of more prey individuals than normal. Heteropteran predators are adapted to feeding on larger prey. A predator that skims nutrient-poor, highly diluted liquids would be likely to kill as many prey as it could capture (Cohen, 2000). Moreover, satiation is a possible reason for decreased prey consumption at higher prey densities, since satiated reduviids spent more time in prey handling due to which rate of prey capture decreased (Ambrose, 1999, 2003; Claver and Ambrose, 2002).

The naturally occurring predators are usually not sufficient to control lepidopteran pests and so augmentation of the predator into the agroecosystem would be necessary to gain successful biological control. However, the performance of biological control agents is also affected by their food sources. Therefore, the proper predator: prey ratio should be determined. The result from this study indicates that the searching efficacy and rate of consumption was maximum when this predator was searching at a density of 4 for all the three tested lepidopteran prey. Thus, the predator–prey ratio of 1: 4 may be optimal for release of this predator to manage and the infestation of these three lepidopteran prey.

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REFERENCES

Akhtaruzzaman, M. and Ahmad, M. (1998) Handling time, interference constant, quest constant and area of discovery of coccinellid predators. *Thai Journal of Agricultural Science* **31(3)**: 342–351.

Ambrose, D. P. (1999) *Assassin Bugs*, Oxford and IBH Publ. Co. Pvt. Ltd.: New Delhi, India and Science Publishers, Inc., New Hampshire, USA, 337pp.

Ambrose, D. P. (2000) Assassin bugs (Reduviidae excluding Triatominae). In: *Heteroptera of Economic Importance*, Schaefer, C. W. and Panizzi, A. R. (Eds). CRC Press: Boca Raton, 695–712.

Ambrose, D. P. (2003) Biocontrol potential of assassin bugs (Hemiptera: Reduviidae). *Journal of Experimental Zoology, India* **6(1)**: 1–44.

Ambrose, D. P. and Claver, M. A. (1997) Functional and numerical responses of the reduviid predator, *Rhynocoris fuscipes* (F.) (Het., Reduviidae) to cotton leaf worm *Spodoptera litura* F. (Lep., Noctuidae). *Journal of Applied Entomology* **121**: 331–336.

Claver, M. A. and Ambrose, D. P. (2002) Functional response of the predator, *Rhynocoris fuscipes* (Heteroptera: Reduviidae) to three pests of pigeonpea (*Cajanus cajan*). *Shashpa* **9(1)**: 47–51.

Claver, M. A., Ravichandran, B., Khan, M. M. and Ambrose, D. P. (2003) Impact of cypermethrin on the functional response, predatory and mating behaviour of a non-target potential biological control agent *Acanthaspis pedestris* Stål (Het., Reduviidae). *Journal of Applied Entomology* **127**: 18–22.

Cohen, A. C. (2000) How carnivorous bugs feed. In: *Heteroptera of Economic Importance*, Schaefer, C. W. and Panizzi, A. R. (Eds). CRC Press: Boca Raton, 563–570.

Cohen, A. C. and Tong, R. (1997) Relative prey weight influences handling time and biomars extraction in *Sinea confusa* and *Zelus renardii* (Heteroptera: Reduviidae). *Environmental Entomology* **26**: 559–565.

Gomez, K. A. and Gomez, A. A. (1984) *Satistical Procedures for Agricultural Research*, 2nd edition. John Wiley: New York.

Hassell, M. P. (1978) *The Dynamics of Arthropod Predator-Prey System*, Princeton University Press: Princeton, 12–49.

Holling, C. S. (1959a) Some characteristics of simple types of predation and parasitism. *The Canadian Entomologist* **91**: 385–398.

Holling, C. S. (1959b) The components of predation as revealed by a study of small-mammal predation of the European pine sawfly. *The Canadian Entomologist* 293–320.

Houck, M. A. (1991) Time and resource partitioning in *Stethorus punctum* (Coleoptera: Coccinellidae) *Environmental. Entomology* **20**: 494–497.

Jeschke, J. M., Koop, M. and Tollrian, R. (2002) Predator functional responses: Discriminating between handling and digesting prey. *Ecological Monographs* **72(1)**: 95–112.

Jeschke, J. M., Kopp, M. and Tollrian, R. (2004) Consumer- food systems: why type I functional responses are exclusive to filter feeders. *Biol Rev Camb Philos Soc* **79**: 337–349.

Luck, R. F. (1985) Principles of arthropod predation. In: *Ecological Entomology*, Huffaker, C. B. and Rabb., R. L. (Eds). Wieley: New York, 497–530.

O'Neil, R. J. (1988) Predation by *Podisus maculiventris* (Say) on Mexican bean beetle. *Epilchna varivestis* Mulsant, in Indiana Soybeans. *The Canadian Entomologist* **20**: 161–166.

O'Neil, R. J. and Stimac, J. L. (1988) Model of arthropod predation on velvetbean caterrpillar (Lepidoptera: Noctuidae) larvae in soybeans. *Environmental Entomology* **17**: 983–987.

Omkar, B. E. and James, B. E. (2001) Predation efficacy of a ladybeetle, *Coccinella transversalis* Fabricius in relation to certain aphids. *Biological Memoris* **27(1)**: 20–26.

Omkar, B. E. and Srivastava, S. (2001) Functional response of a ladybeetle *Coccinella septempunctata* Linnaeus to three aphid species. *Journal of advanced Zoology* **22(1)**: 40–45.

Solomon, M. E. (1949) The natural control of animal populations. *Journal of Animal Ecology* **18**: 1–35.

Williams, F. M. and Juliano, S. A. (1985) Further difficulties in the analysis of functional response experiments and a solution. *The Canadian Entomologist* **117(5)**: 631–640.

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Estimation of foliar pigments and phenol concentrations to assess red spider mite (*Tetranychus urticae* Koch.) tolerance in *Cymbidium* orchids

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ABSTRACT: The foliar pigments, chlorophyll and carotenoids, and total phenol concentrations were estimated for assessing the level of tolerance in seven *Cymbidium* hybrids against red spider mite, *Tetranychus urticae*. The mite infestation was highest in three *Cymbidium* hybrids with moderate levels of total phenol content and higher level of chlorophyll contents. The higher level of survival was observed in *Cym.* Sleeping Nymph 'Glacier' due to 1.8-fold increase in synthesis of total phenol and 3-fold increase in carotenoids to total chlorophyll ratio after infestation. The hybrids with intermediate levels of chlorophyll and higher levels of preformed total phenol contents showed moderate level of infestation and survival. Mite infestation was low in the hybrids *Cym.* Golden Girl and Pine Clash 'Moon Venus' having high amount of chlorophyll, carotenoids and preformed total phenol that protected them from severe mite infestation. Thus, quantification of foliar pigment and phenol concentrations may be used to assess red spider mite tolerance in orchids.

KEYWORDS: Spider mite, orchids, chlorophyll, carotenoids, phenol

INTRODUCTION

Red spider mite (*Tetranychus urticae* Koch.) is a serious pest of *Cymbidium* orchids which are grown commercially for trade as cut flowers and potted plants. The injuries due to sucking the sap from epidermal layer of leaves can be seen as silvery white patches left on the abaxial surface of leaf which usually turns brown or black after a period of time (Nagrare, 2005). Chemical control of this species is very expensive, highly controversial from ecological point of view and does not confer full success because of high fecundity and capability to develop acaricide-resistant races (Warabieda and Borkowska, 2004). Growing tolerant orchid species or cultivars can form a base of pro-ecological approach in controlling *T. utricae* in the commercial

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orchid cultivation. Among the mechanisms of plant resistance to mites, tolerance seems to be particularly important from practical point of view. Quantification of foliar pigments concentration is a useful parameter from physiological perspective to study the variations both among and within the plant species and cultivars as plant pigments viz., chlorophyll and carotenoids are the most important pigments to convert the light energy into chemical energy. Carotenoids are an important component of photosynthetic biomembranes in plants and act as an accessory light harvesting pigment, protect the photosynthetic apparatus from damage by acting as antioxidants during photo-oxidation by quenching reactive oxygen species (Young, 1991). On the other hand, in plants phenol concentrations play an important role against pests and pathogen infestation and higher level of phenols is generally found in resistant cultivars (Sahayaraj *et al.*, 2003). In stress condition or during senescence the concentrations of carotenoids increase and chlorophyll generally decrease. Studies of biotic stresses measuring the concentrations of foliar pigments like chlorophyll and carotenoids; carotenoids to total chlorophyll ratio and total phenol concentrations revealed the presence of heterogeneous metabolic activities in leaves that had been exposed to a pathogen (Thayer and Bjorkman, 1990; Demming-Adams and Adams, 1994). Quantification of foliar pigments and phenols may help to detect biotic stress caused by mite attack before any symptoms of it can be observed visually and also plant's natural defense mechanism against infestation can be evaluated.

We assessed the level of tolerance of seven commercially important *Cymbidium* hybrids by quantification of foliar pigments and total phenol concentrations and the possibility of utilizing these parameters for assessment of tolerance of orchids to mite feeding.

MATERIALS AND METHODS

Plant materials: The experiment was carried out on one year old *ex vitro* hardened plantlets developed through micropropagation of seven *Cymbidium* hybrids viz. Soul Hunt-1, Golden Girl, Show Girl 'Cooksbridge', Lunavian Atlas, Star Guard 'Mc Angel', Sleeping Nymph 'Glacier' and Pine Clash 'Moon Venus' which are maintained under the same growing conditions in polyhouse at National Research Centre for Orchids. Leaf samples of the orchid hybrids were collected pre- and post-infestation by mite for the extraction and quantification of the foliar pigments and total phenol.

Pigments extraction and quantification: Foliar pigments were extracted with 80% acetone (Arnon, 1949). Absorbance of the supernatant was recorded at 440 nm, 645 nm and 663 nm with the help of spectrophotometer (Biomate 5, Thermo Electron Corporation).

Quantification of total phenol: Total phenol was extracted with 80% ethanol and the supernatant was dried up and re-dissolved in distilled water (Sadasivam and Manickam, 1996). Absorbance was recorded at 650 nm after adding Folin-Ciocalteu reagent and 20% sodium carbonate using spectrophotometer.

Mite infestation: Twenty plants of each hybrid were infested with mites at different

TABLE 1. Mite infestation rate and survival per cent of the *Cymbidium* hybrids

Name of *Cymbidium* hybrid	Infestation (CMD cm^{-2})		Survival per cent	
Soul Hunt-1	33.72	Moderate*	35.69	Moderate*
Golden Girl	16.28	Low	20.15	Low
Show Girl 'Cooksbridge'	37.28	Moderate	40.21	Moderate
Lunavian Atlas	56.15	High	22.23	Low
Star Guard 'Mc Angel'	55.32	High	19.06	Low
Sleeping Nymph 'Glacier'	56.24	High	60.15	High
Pine Clash 'Moon Venus'	15.98	Low	17.23	High

*High $\geq$ 50, Moderate = 25–50, Low $\leq$ 25

level selected for the study. The pest population density was measured by counting all the mobile mites on three leaves of each orchid plant on every 10 days. The level of mite's infestation of each plant was calculated as the *cumulative mite days* (CMD), according to the formula: $CMD = \sum 0.5(P_a + P_b) D_{a-b}$ where, P_a and P_b are number of mites per leaf at time a and b, respectively, and D_{a-b} is the number of days between date a & b (Wratten and Lee, 1979). The area of all the checked leaves were measured using a portable Area Meter CI 203 (CID Inc., USA) device and the level of mite infestation was recalculated to 1 cm^2 of the leaf area and expressed as CMD cm^{-2}.

Suvival per cent – Survival per cent was calculated by counting the plants that survived the mite attack and expressed as per cent of total plants studied.

RESULTS

Among the seven *Cymbidium* hybrids under study, *Cym.* Lunavian Atlas and Star Guard 'Mc Angel' exhibited high levels of mite infestation with low survival per cent, whereas *Cym.* Sleeping Nymph 'Glacier' though exhibited highest infestation level but their survival per cent also was high (Table 1). *Cym.* Soul Hunt-1 and *Cym.* Show Girl 'Cooksbridge' showed moderate level of both infestation and survival. Out of rest two hybrids, the infestation level in *Cym.* Golden Girl was low with low survival per cent, whereas *Cym.* Pine Clash 'Moon Venus' exhibited low infestation but high survival per cent.

In pre-infestation stage the foliar pigment, chlorophyll exhibited insignificant variations among all the seven hybrids (Table 2). The carotenoids concentration was highest in *Cym.* Golden Girl followed by *Cym.* Lunavian Atlas and *Cym.* Star Gourd 'Mc Angel' in pre-infestation stage. The total phenol content in this stage was also high in *Cym.* Golden Girl followed by *Cym.* Show Girl 'Cooksbridge' and Soul Hunt-1. In pre-infestation stage *Cym.* Sleeping Nymph 'Glacier' exhibited lowest quantity of both carotenoids and phenol followed by *Cym.* Pine Clash 'Moon Venus'. Whereas, *Cym.* Lunavian Atlas and Star Guard 'Mc Angel' showed same level of carotenoids and phenol concentrations.

TABLE 2. Pigments and total phenol content of *Cymbidium* hybrids pre- and post-infestation

Name of *Cymbidium* hybrid	Total chlorophyll (mg/g fresh leaf tissue)		Carotenoids (mg/g fresh leaf tissue)		Total phenol (mg/g dry weight)	
	Pre	Post	Pre	Post	Pre	Post
Soul Hunt-I	1.006	0.826	1.636	1.450	3.33	2.04
Golden Girl	1.834	0.727	2.604	1.443	4.57	3.13
Show Girl 'Cooksbridge'	1.018	1.103	1.628	1.881	4.25	2.60
Lunavian Atlas	1.717	1.648	2.579	2.451	2.70	1.40
Star Guard 'Mc Angel'	1.271	0.993	2.036	1.754	2.22	2.25
Sleeping Nymph 'Glacier'	2.035	1.126	1.248	2.072	1.67	3.02
Pine Clash 'Moon Venus'	1.031	0.844	1.631	1.497	1.86	2.44
SEm ±	*0.497*	*0.002*	*0.010*	*0.003*	*0.08*	*0.09*
$CD_{0.05}$	NS	*0.006*	*0.029*	*0.009*	*0.23*	*0.26*

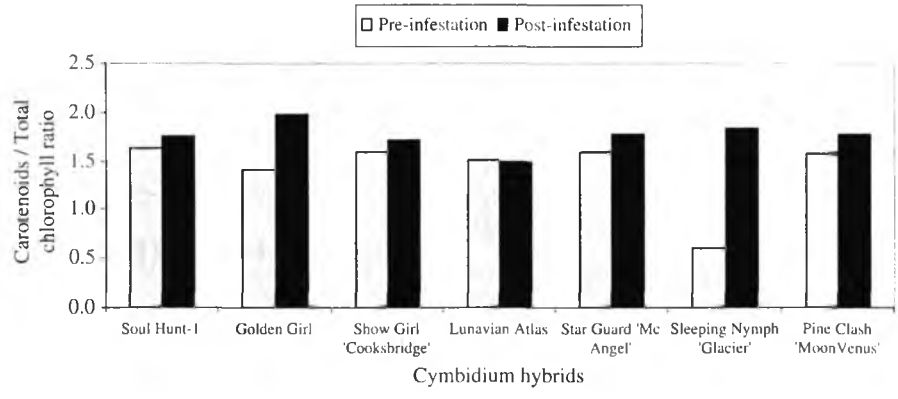

FIGURE 1. Comparisons of pre- and post-infestation carotenoids to total chlorophyll ratio among seven *Cymbidium* hybrids

The total chlorophyll content decreased in all the infested hybrids except in *Cym.* Show Girl 'Cooksbridge'. The carotenoids concentrations also exhibited similar results except in the *Cym.* Show Girl 'Cooksbridge' and Sleeping Nymph 'Glacier' where the concentrations increased after mite infestations. The total phenol content also decreased in four hybrids viz., *Cym.* Soul Hunt-I, Golden Girl, Show Girl 'Cooksbridge' and Lunavian Atlas but, increased in *Cym.* Sleeping Nymph 'Glacier' and Pine Clash 'Moon Venus'. The hybrid *Cym.* Star Guard 'Mc Angel' showed very little difference in total phenol content in pre- and post-infestation stages.

The carotenoids to total chlorophyll ratio were increased in all hybrids except *Cym.* Lunavian Atlas at post-infestation stage (Fig. 1). Maximum increase in this ratio at post-infestation stage was observed in the hybrid *Cym.* Sleeping Nymph 'Glacier'.

DISCUSSION

The mite infestation was highest in *Cym.* Sleeping Nymph 'Glacier' followed by *Cym.* Lunavian Atlas and Star Guard 'Mc Angel', which may be due to the fact that these hybrids contained comparatively moderate level of total phenol and higher level of chlorophyll contents at the pre-infestation stage, which attracted the mites as they feed on the epidermal layers of the leaf. Sahayaraj *et al.* (2003) reported that maximum amount of phenol was present in mite resistant cultivars than moderately resitant and susceptible okra cultivars. Among these three hybrids, *Cym.* Lunavian Atlas and Star Guard 'Mc Angel' had showed low levels of survival due to lower synthesis of total phenol after mite infestation and low carotenoids to total chlorophyll ratio than pre-infestation stage. But *Cym.* Sleeping Nymph 'Glacier' exhibited higher level of survival, due to 1.8-fold increase in synthesis of total phenol after mite infestation. Tomczyk *et al.* (2002) also found an increase in phenol content in the leaves of cucumber plants infested with two-spotted spider mite. Also there was 3-fold increase in carotenoids to total chlorophyll ratio at post-infestation stage than pre-infestation stage in *Cym.* Sleeping Nymph 'Glacier'. The increase in carotenoids to total chlorophyll ratio after biotic or abiotic stress has been found to help the plants to alleviate the stress conditions.

Cym. Soul Hunt-1 and Show Girl 'Cooksbridge' showed moderate levels of infestation and moderate levels of survival. These two hybrids contained intermediate levels of chlorophyll and higher levels of preformed total phenol in their leaves. These two attributes of leaf protected and less facilitated the mite infestation in these hybrids.

Mite infestation was low in the hybrids *Cym.* Golden Girl and Pine Clash 'Moon Venus' though Golden Girl has subsequently higher amount of chlorophyll than Pine Clash 'Moon Venus'. *Cym.* Golden Girl recorded the highest amount of carotenoids and preformed total phenol in its leaves, which protected it from severe mite infestation though once infested its survival also became low as phenol content get reduced after mite infestation. *Cym.* Pine Clash 'Moon Venus' exhibited higher survival per cent due to more phenol synthesis after mite infestation.

In the present study, the mite tolerant *Cymbidium* hybrids with requisite characters like foliar pigments and phenol play important role in screening mite tolerance species or cultivars and these parameters can be used to assess mite tolerance. Most of the commercially important orchid species and hybrids that are grown in protected condition are attacked by mites as well as other pests, which ultimately affect the quantity and quality of the flowers. So it is recommended to grow the cultivars with high to moderate levels of pests and disease tolerance which will reduce the yield loss, cost of cultivation and also maintain the ecological safeguards (Sahayaraj *et al.*, 2003). The *Cymbidium* hybrids with high levels of preformed phenol content like *Cym.* Soul Hunt-1 and Show Girl 'Cooksbridge' and higher post-infestation phenol content as in *Cym.* Sleeping Nymph 'Glacier' and Pine Clash 'Moon Venus' can be recommended for large-scale commercial cultivation as they are highly tolerant to mite infestations owing to their high concentrations of phenol and foliar pigments. Using these parameters biotic stress and plant's natural defense can also be detected before

appearance of any visual symptoms of pest infestation. Further, these mite tolerant hybrids can also be used as parents in mite or pest resistance breeding programmes.

REFERENCES

Arnon, D. I. (1949) Copper enzyme in isolated chloroplasts, polyphenol oxidase in *Beta vulgaris*. *Plant Physiology* **24**: 1–15.

Nagrare, V. S. (2005) *Technical Bulletin: Pests of orchids and their management*, National Research Centre for Orchids: Pakyong, Sikkim, p. 18.

Sadasivam, S. and Manickam, A. (1996) *Biochemical Methods*, New Age International (P) Limited: New Delhi, p. 256.

Sahayaraj, K., Prabhu, J. N. and Martin, P. (2003) Screening of mite resistant okra varieties based on morphology and phytochemistry. *Shashpa* **10**: 147–150.

Tomczyk, A., Schmitt, A. and Maunch Mani, B. (2002) Changes in secondary plant metabolites in cucumber leaves induced by spider mites and plant growth promoting rhizobacteria (PGPR). *Bulletin-OILB-SROP* **25**: 67–70.

Wratten, S. D. and Lee, L. (1979) Duration of cereal aphid populations and the effects on wheat yield and quality. In: *Proceeding of British Crop ProtectionConferance – Pest and Disease*, 1–9.

Warabieda, W. and Borkowska, B. (2004) Chlorophyll α fluorescence as a diagnostic tool for assessment of apple resistance against two-spotted spider mite (*Tetranychus urticae* Koch.). *Electronic Journal of Polish Agricultural Universities*, Horticulture Volume 7, Issue 1.

Thayer, S. S. and Bjorkman, O. (1990) Leaf xanthophyll content and composition in sun and shade determined by HPLC. *Photosynthesis Research* **23**: 331–343.

Demming-Adams, B. and Adams, W. W. (1994) Capacity for energy dissipation and flexible photosystem II efficiency in plants acclimated to light stress. *Australian Journal of Plant Physiology* **22**: 249–260.

Young, A. (1991) The photoprotective role of carotenoids in higher plants. *Physiology Plantarum* **83**: 702–708.

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Biology of *Helopeltis theivora* (Hemiptera: Myridae) infesting tea

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ABSTRACT: The tea mosquito, *Helopeltis theivora* (Hemiptera: Miridae) is responsible for considerable crop loss in tea in India. For rearing this insect in the laboratory tubes made of polyester film were found most suitable. Total developmental period of the insect from egg to adult stage varied between 9 and 29 days. *H. theivora* bred throughout the year resulting in the production of overlapping generations. Average longevity of females was 48.2 days whereas males lived only for 28 days. Females laid an average of 6.74 eggs per day and in tea fields the most preferred site for oviposition was the broken end (stub) on bushes after plucking the shoots. Among the three different hosts, viz. *Camellia sinensis (tea) C. japonica* (ornamental tea) and *Maesa indica* (weed), tea mosquito had the highest fecundity on *C. sinensis*, though females lived longer on *M. indica*. Among the tea cultivars, UPASI-9 and UPASI-22 were more susceptible to infestation than the others. Life table studies revealed that net reproductive rate was highest on *C. sinensis* and lowest on the *C. japonica*. Populations of *H. theivora* reached a peak in September–October and declined during April and May. Though a wet weather pest, heavy rainfall adversely affected its population. High temperature and high relative humidity were also negatively correlated to its numerical abundance. The insects could cause 18% loss in crop when 10% of the shoots were infestated. The field study further established an economic threshold level of 4.7% infestation. The mymarid, *Erythmelus helopeltidis* was the most dominant parasitoid, inflicting up to 82% mortality of eggs in tea fields.

KEYWORDS: tea mosquito, *Helopeltis theivora*, *Camellia sinensis*, life table, crop loss, *Erythmelus helopeltidis*, seasonal abundance

INTRODUCTION

Species belonging to the genus *Helopeltis* (Hemiptera: Miridae) enjoy a wide distribution, extending from Western Africa to New Guinea and Northern Australia. They infest several economically important crop plants such as tea, cashew, guava, cocoa, black pepper, apple, grapes and neem besides several spieces of weeds. Different

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species of *Helopeltis* attack tea (*Camellia sinensis*) in different countries and in India *Helopeltis theivora* Waterhouse, commonly called the tea mosquito is an important of tea, especially in Assam and certain parts of Kerala. The two earliest references to the occurrence and damage by *H. theivora* are those of Anstead and Ballard (1922), Shaw (1928). Subsequently, Rau (1940) provided information on the pest status and control of this species in South India. More recently, Das (1984) studied its life history in North-East India. Despite its importance to the Indian tea industry, there had been very few attempts to study in detail its biology, ecology and economic threshold level, though several articles have been published on the chemical control of this pest. In the present paper, we report the results of our studies on the life history, life table and population trends of *H. theivora* along with details on crop loss and the economic threshold level for adopting chemical control measures.

MATERIALS AND METHODS

Mass rearing

For rearing *Helopeltis* in large numbers in the laboratory, the usefulness of transparent plastic jars and perforated polyester tubes was compared. Mouths of transparent plastic jars (25.5 cm × 11 cm — 4 capacity) were covered with nylon mesh. Seven to ten tea shoots, each of three leaves and a bud, were wrapped together with wet cotton and again by a strip of polythene. These bunches of shoots were inserted tightly into a glass vial (5 cm long × 2.5 cm wide) containing water. Two such glass vials were kept in each jar (Fig. 1). Nymphs and adults collected from the field were introduced into the jars and in each jar, 10–12 nymphs were allowed to feed on tender shoots. Every day, the vials were replaced and the nymphs carefully transferred to new shoots. This was continued till the emergence of adults. Adults were sexed, paired and reared in separate containers.

Another rearing method was developed using transparent polyester film (100, u). A piece of film measuring about 11 cm × 15 cm was made into a tube and its one end closed with another piece (5 cm × 5 cm) of finely perforated polyester film. A thermacol sheet measuring about 28 cm × 39 cm × 1 cm was fitted into a plastic tray, half filled with water. Holes were made on the thermacol sheet and one or two fresh tea shoots were inserted into each holes (Fig. 2). Care was taken to dip the stem tip into water to keep the short turgid. Insects were released into the tubes and their activities monitored periodically.

After mating, females oviposited into the shoots and the egg laden shoots were cut and spread on a tray lined with wet filter paper. In another experiment, a round glass trough with a little water was fitted with a thermacol sheet with many perforations. The egg laden shoots were kept straight in the holes, without touching the water underneath. Another set of fresh tea shoots (without eggs) were inserted into a few other holes, immersing the stem part in the water. In the center of the thermacol sheet a small hole was made to change water, whenever required (Fig. 3). The newly emerged nymphs fed on the fresh shoots kept in the trough. After a few hours, nymphs were transferred to the polyester rearing tubes.

FIGURE 1. Rearing of tea mosquito – Jar Method.

TABLE 1. Life history of *H. theivora* on three host plants

Life stage/particulars	Host plant		
	Camellia sinensis *	*Maesa indica*	*Camellia japonica*
Pre-Oviposition period (days)	4.80 ± 0.59	4.60 ± 0.45	4.20 ± 0.77
Oviposition period (days)	47.60 ± 1.82	44.80 ± 1.25	32.00 ± 0.28
Incubation period (days)	9.20 ± 0.33	7.20 ± 0.52	6.20 ± 0.52
Duration (days)			
I instar	3.80 ± 0.33	3.40 ± 0.22	4.80 ± 0.52
II instar	3.40 ± 0.36	4.60 ± 0.46	5.00 ± 0.49
III instar	2.80 ± 0.18	2.80 ± 0.33	3.20 ± 0.33
IV instar	2.80 ± 0.18	3.00 ± 0.40	3.00 ± 0.57
V instar	3.00 ± 0.28	3.60 ± 0.36	4.80 ± 0.52
Total nymphal duration (days)	15.80 ± 0.87	17.40 ± 0.46	20.80 ± 1.25
Total developmental time (days)	25.00 ± 0.89	24.60 ± 0.61	27.00 ± 1.26
Adult Longevity (days)			
Male	28.00 ± 4.50	25.80 ± 1.80	19.80 ± 0.52
Female	48.20 ± 2.64	49.80 ± 3.70	36.80 ± 1.58
Fecundity (No. eggs)	170.17 ± 31.70	45.40 ± 20.52	102.20 ± 9.42
% of eggs hatched	96.00	92.00	80.00
% nymphs reaching adult stage	94.00	87.00	78.00
Sex ratio (Female:Male)	1:0.92	1:0.98	1:1.07

*On the tea clone UPASI-9.
± Standard error of the mean of 10 replications.

TABLE 2. Influence of temperature on the life history of *H. theivora*

Life stages/particulars	Duration in days (Mean + SE)*		
	20 ± 1°C	25 ± 1°C	30 ± 1°C
Pre-Oviposition period	6.0 ± 0.80	4.8 ± 0.59	2.6 ± 0.36
Oviposition period (days)	10.6 ± 0.22	7.2 ± 1.37	4.6 ± 0.46
Incubation period (days)	9.8 ± 0.52	9.2 ± 0.33	4.4 ± 0.46
Duration (days)			
I instar	4.0 ± 0.28	3.6 ± 0.46	3.2 ± 0.44
II instar	3.6 ± 0.22	3.2 ± 0.33	2.0 ± 0.00
III instar	3.0 ± 0.00	2.8 ± 0.33	1.8 ± 0.18
IV instar	3.4 ± 0.22	2.6 ± 0.22	2.4 ± 0.22
V instar	5.0 ± 0.28	2.8 ± 0.33	2.6 ± 0.36
Total nymphal duration (days)	19.00 ± 0.75	15.00 ± 1.17	12.00 ± 0.85
Total developmental time (days)	28.80 ± 0.77	24.20 ± 1.25	16.4 ± 0.73
Adult Longevity (days)			
Male	22.6 ± 1.69	23.2 ± 0.77	9.0 ± 0.63
Female	32.4 ± 0.92	50.4 ± 1.82	16.2 ± 1.14
Fecundity (eggs)	19.8 ± 2.91	135.4 ± 16.27	19.2 ± 2.02

*Standard error of the mean of 10 replications

TABLE 3. Varietal screening of tea clones against Tea mosquito infestation

Clone	No. of eggs laid/female	No. of puctures/shoot/ day/insect
UPASI-1	**9**	5.8b
UPASI-2	**14**	**9**.70c
UPASI-3	**14**	10.7c
UPASI-7	**10**	8.59c
UPASI-8	**8**	6.28b
UPASI-9	17	12.73c
UPASI-10	1	2.73a
UPASI-11	8	6.27b
UPASI-1	25	3.39a
UPASI-13	**9**	5.72b
UPASI-14	**2**	2.77b
UPASI-15	**3**	3.06a
UPASI-17	**2**	2.20a
UPASI-22	**16**	9.19c
AKK-1	**11**	12.57c
ATK-1	8	6.02b
CDP = 0.05		2.21

Means followed by same letter are not significantly different at 5% level.

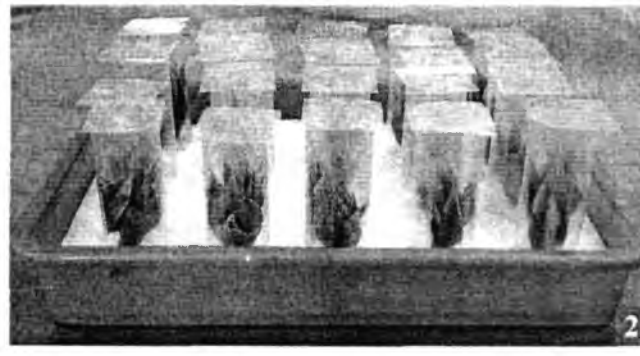

FIGURE 2. Rearing of tea mosquito – Tube Method.

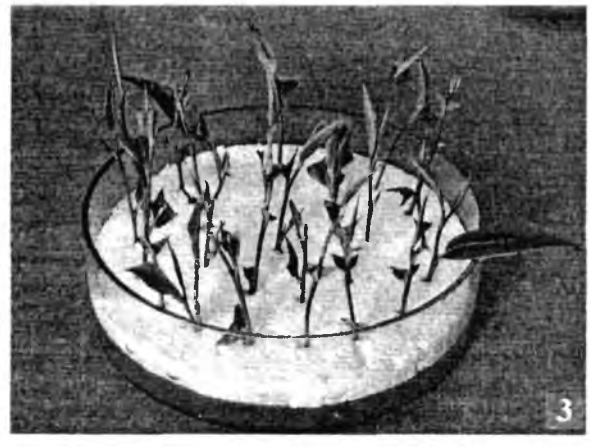

FIGURE 3. Mass rearing of eggs of *H. theivora*.

Life table and preference to cultivars

Rearing was done at 25 ± 1°C and 85 ± 5% RH on *Camellia sinensis*, *Maesa indica* (Myrsinaceae) (a common weed in tea fields) and *Camellia japonica* (an ornamental tea species). Data were recorded daily on the number of eggs laid, number of nymphs attaining adults stage and adult sex ratio. Shoots of the clones (cultivars) UPASI-1, 2, 3, 7, 8, 9, 10, 11, 13, 14, 15, 17, AKK-1 and ATK-1 were exposed to *Helopeltis* and the number of feeding punctures was recorded as a part of the clonal screening programme. Studies on life history were carried out at 20 ± 1°C, 25 ± 1°C and 30 ± 1°C on *C. sinensis* to determine the influence of temperature. Data on feeding rate and fecundity were recorded. Experiments were also carried out to find out the preference for oviposition site. Twenty mated females were allowed to oviposit and

the distribution of eggs in the shoots was observed. Shoots and broken ends of plucked shoots (stubs) were collected from the field and examined for oviposition sites.

Life table of *H. theivora* was studied on *Camellia sinensis*, *Maesa indica* and *Camellia japonica*. Females, fed on the particular host plant, were allowed to oviposit in the same host. One hundred eggs were observed for hatching and nymphs and adults were reared in subgroups. Immediately after hatching, nymphs were transferred to shoots of the respective host plant kept in ten polyester tube cages. Adults emerging on a particular day were paired and released in separate cages @5 pairs/cage.

Fecundity of females was recorded till their death. The number of eggs laid on each day by each female was recorded. Similarly, the mean number of eggs laid and the total number of females survived on the previous day were noted. In order to arrive at the number of female progeny (mx), the number of eggs laid per female was divided by 1.92 (Female (F): Male (M) ratio = 1 : 092) for *Camellia sinensis*, 1.89 (F:M = 1 : 0.89) for *Maesa indica* and 2.07 (F:M = 1 : 0.7) for *Camellia japonica*. Daily, observations were made on hatching of eggs to emergence and death of adults, which provided the values for life table (1x). Life tables were constructed as described by Birch (1948); Atwal and Bains (1974).

Net reproductive rate (RO), mean length of generation time (TC) and innate capacity for increase (rm) were the basic parameters used to determine the growth of population. Doubling time was determined following the formula of Campbell and Mackauer (1975) while stable age distribution was calculated following Dhandapani and Balasubramanian (1984).

Seasonal distribution

The incidence of tea mosquito was recorded for three years, from 1995–1997 at Vandiperiyar (Idukki District, Kerala) in an experimental plot of 100 bushes, which was not treated with insecticides. Percentage of infestation was assessed every month by collecting 100 tea shoots at random and counting of infested shoots. These shoots were also used to collect information on the incidence of egg parasitism.

Data on rainfall, temperature and relative humidity were collected from the meteorological observatory. The influence of weather parameters on seasonal abundance was ascertained using multiple regression analysis.

Assessment of crop loss and ETL

The experiment on crop loss appraisal was also conducted in a tea field in Vandiperiyar where severe tea mosquito infestation was noticed. There were four treatments with seven replications and each replicate consisted of a plot of 100 bushes. Pre treatment assessments were made on yield levels as well as on the percentage of infestation. The treatments included of (1) Cypermethrin (Cymbush 25 EC@120 ml/ha), (2) fluvalinate (Mavrik 25 EC @200 ml/ha), (3) alphamethrin (Alphaguard 10 EC @200 ml/ha) and (4) untreated control. Insecticides were applied with hand operated knapsack sprayers, using spray volume of 400 l/ha. The tea shoots harvested at each plucking round was

weighed and the percentage of infestation was recorded. Economic Threshold Level (ETL) was calculated using the formula of Mumford and Norton (1984).

$$ETL = C/PDK$$

where, C = Cost of chemical control, P — Price of the tea, D — The loss in crop (Kg/ha) associated with 1% infestation, K — The reduction in the pest attack due to pesticide application.

Natural enemies

Periodical surveys were undertaken in the tea estates of Anamallais (Coimbatore, Tamil Nadu), Vandiperiyar and Peermade (Idukki District, Kerala) to find out the natural enemies of *H. theivora*. One hundred tea shoots containing eggs of *H. theivora* were collected from 100 plants collected at random from selected tea fields and placed in plastic containers (750 ml capacity) fitted with a glass tube (15 × 2.5 cm) to collect egg parasitoids. The container (except the glass tube) was completely covered with black paper (Sundararaju, 1993), which facilitated the observation only in the glass tube. The shoots were immersed in 0.1% carbendazim solution for 10 min to prevent fungal contamination. After treatment, samples were air dried to remove moisture. For general observation, hand lens and stereo microscope were used. For morphometric study, semi permanent slides were prepared and measurements were taken using ocular and stage micrometer in research microscope.

Appropriate statistical methods were used for analysis of data. Data on seasonal incidence and weather factors were subjected to multiple regression analysis using SPSS 6.0 package.

RESULTS AND DISCUSSION

Mass rearing

When reared inside polyester film tubes, nymphal mortality was as low as 5.8% in comparison to 22.6% in jar method. Inside each jar with a bunch of tea shoots, only two pairs of insects could be reared at a time, while in the case of tube method only one shoot was required for each adult/nymph per day and replacement of shoots was easy. In the tube method, damage to insects was reduced to a great extent as reflected by the high survival rate (>90%) of both adults and nymphs. Similarly, the percentage of hatching was as high as 96% when the egg laden shoots were kept in an upright position on wet thermacol whereas leaving them flat on a wet filter paper resulted in only 40% hatching. Hartley (1965) reported that mirid eggs failed to hatch from desiccated shoots. By keeping the egg laden shoots upright in the wet thermacol, they remained turgid, which in turn helped to achieve higher percentage of hatching.

Life history

Egg

The egg is white, cylindrical and slightly curved. The egg is completely inserted in to the tender plant tissue except for the respiratory horns, which project from the surface. Average length of egg is 1.19 mm with a maximum width of 0.22 mm. The longer respiratory horn is 0.41 mm long while the short one is 0.28 mm long . Operculum is 0.10 mm wide.

Incubation period varied accordingly to season. From June to November incubation period was eight to ten days (9.5 ± 0.33 days). Developmental period was short during hot and humid weather (6–7 days). During the other months, incubation period was prolonged (11–12 days). Majority of eggs hatched out between 6.00 and 9 a.m. or between 4.00 and 6.00 p.m.

Nymphs

There are five nymphal instars. The newly hatched nymph, light orange in colour, measured about 1.49 mm. After a couple of hours, head, antennae, legs and abdomen turned light brown. Antennae and thoracic segments bear tiny yellowish hairs. Eyes pink; antennae longer than body. Rostrum extends upto fourth abdominal segment. The characteristic scutellar horn and wings absent. The active first instar nymphs confined themselves to the bud and first leaf of the tea shoot. Duration of this stage ranged between 3 and 5 days. Head, antennae, legs, thorax and abdomen of second instar deep orange in colour and body measured about 2.00 mm. Pale markings seen all over the body; scutellar horn visible. Duration of second instar varied between 2 and 4 days. Third instar has the body reddish green and measured about 3.00 mm long. Scutellar horn distinct, with a red tip; tiny wing buds visible. Secondary sexual characters not distinct. The nymph moulted after 2 to 3 days. Fourth instar nymphs greenish yellow and measured about 4.17 mm long. Wing pads became dark but sexes could not be externally identified at this stage. Duration of this instar was also 2 to 3 days. Fifth instar nymphs are reddish green in colour with the abdomen green. Nymph measured about 5.00 mm long and resembled adults but for body colour and wings. Wing pads overlap scutellar horn. The fifth instar moulted into adult after 2 to 4 days. Sexes could be identified on the basis of external genitalia; in males tip of abdomen is blunt whereas in females, a groove like structure appeared in place of future ovipositor.

The total developmental period, from first to fifth instar, varied between 19 and 29 days. Usually, the instars moulted on the lower surface of the leaf. Before moulting, the tips of wing-pads darkened and during the final moult, darkening started three days before moulting. Normally, nymphs did not feed for a few hours before ecdysis.

H. theivora bred throughout the year and there was overlapping of generations. During day time both nymphs and adults hid themselves among the lower tier of foliage and when disturbed moved rapidly under the leaves but seldom fell to the

ground. Nymphs rarely migrate to adjacent tea bushes and usually completed their life cycle on a single brush.

Adult

The newly emerged yellowish brown adults turned metallic black within an hour. Antennae black, basal segments with pale markings, four segmented, and about twice the length of legs. Head black; eyes oval and prominent. Wings black and abdomen green. Both males and females have the scutellar horn, which is gently curved with a funnel shaped swollen apex.

Female, black with yellow spots on thorax and head and measured 7.43 mm long. The female, larger than male, is equipped with a reddish brown curved ovipositer. Average longevity 48.2 days. Male generally paler than female and measured about 6.31 mm long. Average longevity was 28.0 days.

The adult tea mosquito is swift but not a strong flyer. They remained active throughout the day. In the field there was a preponderance of females and the female: male ratio was 1:0.92. Females mated four days after emergence whereas males were ready for mating within two days. Multiple matings were common. Mating took place both at day and night. Duration of mating ranged between 1 h 30 min, and 3 h 10 min, and a single male mated up to 12 times.

Adult female started laying eggs within a few hours after mating. Prior to ovipositing, female actively fed and searched for oviposition sites. The blunt portion of the egg was first inserted into the green tissue and the ovipositor was gently withdrawn leaving the egg fully inserted in to the plant tissue. Ovipositing time varied from 2.5 to 4.0 minutes. A single female laid up to 325 eggs with an average of 6.74 eggs per day in her life span of 48.2 days.

Eggs were laid into the green shoots, broken ends of plucked shoots, leaf petioles, lower side of the midrib and axillary buds. The most common and preferred site was broken ends of plucked shoots, which harboured 52% of the eggs in the field. Other preferred sites for oviposition were green shoots (26%) and leaf petioles (17%). Eggs were laid singly or in small batches of 2 to 3 and occasionally a dozen eggs were closely laid. A longitudinal streak appeared at the site of oviposition.

Data relating to the comparative biology of *H. theivora* on *Camellia sinensis*, *Maesa indica* and *Camellia japonica* are presented in Table 1. The total developmental period was 25 days on *C. sinensis*, 24.6 days on the *Maesa indica* and 27 days on *C. japonica*. The sex ratio also varied when reared on different host plants. Fecundity was, highest on *C. sinensis*, whereas longevity of females was more on *M. indica*.

Das (1984) reported that in northeast India, eggs of *H. theivora* had short incubation period during June–August but hatching was delayed in January. Fecundity of *H. theivora* was relatively high when compared to that of other species of *Helopeltis* as reported by Lean (1926) on cotton, Sudhakar (1975) on Guava, and Sundararaju (1996) on cashew. The sex ratio also varied depending on the host plants (Balasubramanian *et al.*, 1988; Sundararaju, 1996). Among the phenological stages, broken end (stubs) of plucked tea shoots was the most preferred site of oviposition. Sundararaju

(1996) found that nearly 50% of eggs of *H. antonii* were laid on tender shoots of neem and about 25% on mature shoots. *H. antonii* could multiply in a very short time on cashew shoots than on guava.

Temperature influenced developmental period and longevity (Table 2). Adults lived longer at 25°C and longevity was lower at 20°C and 30°C. Nymphal duration was shorter at 30°C and longer at 20°C, in comparison to that at 25°C. Adult females laid more number of eggs per day at 30°. The number and width of feeding punctures were also more at higher temperatures.

The results of the present study are similar to the reports on *Helopeltis antonii* on cashew (Pillai and Abraham, 1974) guava (Sudhakar, 1976) and tea (Jeevaratnam and Rajapakse, 1981). Ambika and Abraham (1979) reported that 25°C was most suitable for fertilization and oviposition and 28°C was ideal for embryonic development and progeny production in *H. antonii* on cashew. Higher temperature tends to raise the metabolic rate that leads to greater feeding activity in hemipteran insects (Rhamhalinghan, 1987). At high temperature, *H. theivora* laid more eggs per day but the longevity of females was reduced drastically and this is at variance with the results reported by Pillai *et al.* (1976) and Pillai and Abraham (1974) on *H. antonii*, where males lived for relatively longer period than females on cashew seedlings.

Preference to cultivars

Among the tea clones (cultivars) screened, UPASI-2, 3, 7, 9, and 22 and AKK-1 were the most susceptible; they received more than 7.34 punctures/shoot/day and as high as 12.73 in a day. (Table 3). UPASI-10, 12, 14, 15 and 17 were less susceptible and while UPASI-1, 8, 11 & 13 and ATK-1 were moderately susceptible. Fecundity rate was highest UPASI-9 and 22.

No tea cultivar was immune to infestation by *H. theivora*; however the cultivar UPASI-9, the most popular planting material in South India, was the most preferred. Similarly in northeast India, the most commonly used clone, TV-1 was more susceptible to tea mosquito infestation (Raj, 1992). Green (1901) had reported that pure Assam type tea was practically immune, while in the case of hybrids, those with predominant Chineric characters were more susceptible to feeding by *H. theivora*. Anstead and Ballard (1922) also observed that in Southern India, China varieties and their hybrids were more susceptible to attack than the other varieties.

Life table

Life table statistics of *H. theivora* on *Camellia sinensis*, *Maesa indica* and *Camellia japonica* are given in Table 4. The pre-oviposition period ranged from 25 to 28, 26 to 29 and 28 to 31 days of pivotal age when the insect was reared on *C. sinensis, M. indica* and *C. japonica*, respectively. The survival of immature states (1x) from egg to adult emergence was 0.82, 0.73 and 0.56 adults per individual on the respective host plants. The first female mortality within the cohort occurred on the 20th, 13th and 14th day after the emergence of adult female and increased slowly thereafter. Females' contribution was the highest in the life cycle on the 10th and 12th day of pivotal age

TABLE 4. Life table of *H. theivora* on different host plants

Particulars	Host plants		
	Camellia sinensis	*Maesa indica*	*C. japonica*
Gross reproduction rate, Σmx	170.31	196.30	109.18
No. of female progeny/female/day	3.62	4.27	3.43
Net reproductive rate, Ro	129.44	117.36	46.26
Mean length of generation, Tc (days)	42.40	43.09	43.49
Innate capacity for increase in number (rc)	0.12	0.11	0.01
Arbitrary rm (rc)	0.10–0.13	0.10–0.12	0.08–0.10
Precise value of intrinsic rate (rm)	0.12	0.11	0.09
Σ e-7 rm × 1× mx = 1096.6 females/day			
Corrected generation time, Tc (days)	39.41	41.80	40.79
Finite rate of increase, λ (females/day)	1.13	1.12	1.10
Weekly multiplication of the population	2.37	2.22	1.93
Doubling time (days)	5.62	6.08	7.37
Stable age distribution (%)			
Eggs	69.21	57.64	53.72
Nymphs	27.34	39.06	43.27
Adults	3.45	3.19	3.02

on *C. sinensis* and *M. indica*, whereas in the case of *C. japonica* it was on the 13th day. Production ceased by the 48th and 33rd day after first oviposition. The data on intrinsic rate of natural increase (rm) and the generation time (Tc) of the bug are given in Table 4.

Host plants significantly influence vital features such as the rate of development, survival and reproductive potential of insects which ultimately determined the rate of population build up. A maximum net reproductive rate (Ro) and innate capacity for increase in number (rm) and short doubling time (DT) were observed on *C. sinensis* which indicated that outbreak or population eruption *H. theivora* could occur at a very short time on tea plants than on other host plants. A shorter generation time usually favoured high reproductive fitness. Even though gross reproductive rate was high in *Maesa indica* than on tea, the net reproductive rate was highest on the latter. This is due to the survival of more adult females and the high fecundity. Actually the eggs laid by young females helped to increase the population and the older females helped to maintain the population during unfavourable conditions. Based on the life table studies, it could be concluded that under favourable conditions, *H. theivora* could multiply more rapidly on tea than on other host plants.

Feeding behaviour

Nymphs and adults of *H. theivora* sucked plant sap from tender stems, young leaves, petioles and bugs. They usually did not attack lignified or senescent tissues. There was a direct correlation between the age of the instar and width of the feeding punctures. In general, feeding punctures made by adult females were comparatively larger than

TABLE 5. Assessment of crop loss due to *H. theivora* infestation

Treatments	Cycle yield* kg made tea/ha	% increase over control	% infestation (post treatment)
Cymbush 25 EC	8980.3	18.04	3.43a
Mavrik 25 EC	8665.2	13.90	5.29ab
Alphaguard 10 EC	8996.1	18.25	2.29a
Untreated control	7607.9		13.86b
CD $P = 0.05$			9.07

*Based on yield for 6,700 bushes/ha (3 year cycle) adjusted to pre-treatment yield; Made tea was calculated at an out turn of 23.3%.

those made by males; during oviposition still large punctures were made. Feeding by early instar nymphs resulted in smaller spots of 0.4 to 1.75 mm dia whereas later instars and adults produced relatively larger spots of 2 to 5 mm dia. Each feeding by an adult lasted upto 4 min. Feeding activity reached a peak during early morning (05–07 h) and late evening (16.00–19.00 h) hours. However, on bright days feeding had been observed even at noon but it was noticeably less after 09.00 h.

The number of punctures per shoot varied with the intensity of feeding and number of insects feeding on it. A single adult, in 24 h could make 90 to 180 feeding punctures on a shoot. A female in its total life span of 65 days produced as high as 9731 punctures with an average of 179 punctures per day. Obviously, due to this type of feeding behaviour, a relatively small population of *H. theivora* could cause considerable damage to tea field.

Das (1984) observed that a single late instar nymph could produce a maximum of 80 feeding spots in 24 h under laboratory conditions. Though second instar nymphs made more number of punctures, the width of the punctures was comparatively smaller than those made by the later instars. It was also found that a single adult female in its life span could damage a leaf area, which was much more than the total damage inflicted by all the nymphal instars and adult male. This observation differs from that of Devasahayam and Nair (1986), who reported the final instar nymph of *H. antonii* as the most damaging life stage on cashew.

Seasonal abundance

The seasonal prevalence of tea mosquito during 1995–1997 is presented in Fig. 4. Incidence of the pest was high during July to December and low during January to June. *H. theivora* bred throughout the year and their numbers fluctuated during different months. The population usually began to built up in the months of June/July, reached a peak in September/October or November. The smallest populations usually occurred in the dry, hot months from March to May. Certain tea areas which are close to swamps and forests were infested almost throughout the year.

Adults and nymphs of tea mosquito preferred dark humid and shaded areas. They

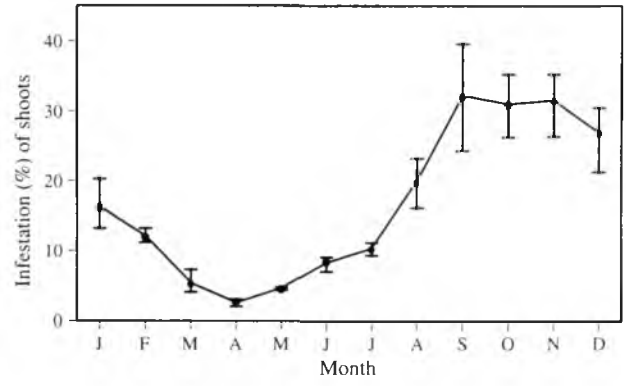

FIGURE 4. Seasonal variation in infestation by *H. theivora* (Average of three year's data: 1995–97).

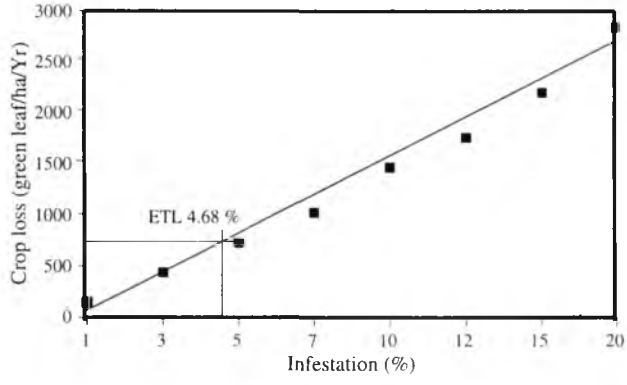

FIGURE 5. Crop loss in tea due to infestation by *H. theivora*.

were active during early morning and late evening hours. During day time they usually hid among bushes or among the weeds present in tea fields. The multiple regression equation fitted with certain abiotic factors to predict the percentage of infestation was $(Y) = 10.30 - 0.034$ Rainfall -0.853. Maximum temperature -1.11 Minimum temperature -0.33 Maximum relative humidity $+0.87$ Minimum relative humidity ($R^2 = 0.44065$). Eventhough *H. theivora* is a wet weather pest heavy rainfall adversely affected its population. High temperature and high relative humidity had a negative influence on the populations while low relative humidity had a significant positive effect.

In the field, peak activity of tea mosquito was observed at dawn and dusk when there was a rapid change in light intensity. Similar trend was observed on cashew (Jeevaratnam and Rajapakse, 1981), where the number of *H. antonii* was significantly more in morning and evening. Feeding activity of this pest on cashew was high before

9 a.m. and after 4 p.m. (Abraham and Nair, 1981). Ahmed (1996) recorded a peak in the population of *H. theivora* in tea fields of Bangladesh during September, a decline in October and November and very low incidence during December to March. The build up of *H. theivora* population on tea in Bangladesh was mainly related to increased day length, temperature, humidity, cloud cover and rainfall. The population trend appeared almost similar to that observed in South India.

When the egg-laden shoots collected from the field were kept in the natural enemy observation chamber, adults of the egg parasitoid *Erythmelus helopeltidis* (Gahan) (Mymaridae) started emerging from the eggs of *Helopeltis* after 28–34 days. Analysis of data on field level parasitism during June 1997 to February 1998 revealed that the average incidence of parasitism was 28%. The percentage of parasitism increased from June to October and declined thereafter. A peak of 82% parasitism was noticed during September 1998 which declined to 51% in October and to 8% in February. In the laboratory, gravid female parasitoids were allowed to oviposit in the hosts eggs and the percentage parasitism was as high as 90%.

There were no efficient natural enemies for *H. theivora* except for the egg parasitoid *Erythmelus helopeltidis* Gahan. This parasitoid was recorded earlier by Devasahayam and Nair (1986) from the eggs of *H. antonii* infesting cashew, and also from the eggs of the tingid, *Ophiomyia lantanae* attacking *Lantana camara* in Uttar Pradesh and Andhra Pradesh (Rao and Hayat, 1986).

Crop loss and damage potential

The loss in crop was as high as cent per cent during periods of severe attack. Yield data obtained for two and half years under different treatments are given in Table 5. The crop harvested from the pesticide treated blocks was higher than that obtained from the blocks under untreated control. It was estimated from this study, that at 10% infestation the loss in crop would be 18%. Under the above conditions, which was prevalent in the experimental area, the ETL was assessed as 4.68% infestation (Fig. 5).

Earlier studies had shown that crop loss due to tea mosquito could be near total if the attack was very severe (Rao and Murthy, 1976). Average crop loss due to *Helopeltis* was 150 kg made tea per ha in Bangladesh (Ahmed, 1996). Damage by *H. theivora* resulted in almost 95% crop loss if no biological or chemical control measures were adopted (Way and Khoo, 1989). The ETL for *H. theivora* was almost similar to that recommended for *H. schoutedeni* affecting tea in Central Africa during the main cropping season (Rattan, 1987).

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REFERENCES

Abraham, C. C. and Nair, G. M. (1981) Effective management of the tea mosquito bugs for breaking the yield barriers in cashew. *Cashew Causerie* **3(1)**: 6–7.

Ahmed, M. (1996) Relationship between infestation intensity and crop loss by *Helopeltis* in tea. *Tea Journal of Bangladesh* **32(1&2)**: 20–30.

Ambika, B. and Abraham, C. C. (1979) Bioecology *Helopeltis antonii* Sign (Miridae: Hemiptera) infesting cashe-trees. *Entomon* **4**: 335–342.

Anstead, R. D. and Ballard, E. (1922) Mosquito blight of tea. *Planters Chronicle* **17**: 443–455.

Atwal, A. S. and Bains, S. S. (1974) *Applied Animal Ecology*, Kalyani Publishers: Ludhiana, p. 245.

Balasubramanian, G., Chelliah, S., Balasubramanian, M. and Gopalan, M. (1988) Life table and intrinsic rate of increase of *Spodoptera litura* Fabricius on castor and cotton. *Entomon* **13**: 141–145.

Birch, L. C. (1948) The intrinsic rate of natural increase of an insect population. *Journal of Animal Ecology* **17**: 15–26.

Campbell, A. and Mackauer, M. (1975) Effect of parasitism by *Aphidicis smithi* (Hymenoptera: Aphididae) on reproduction and population growth of tea aphid (Homoptera: Aphidae). *Canadian Entomologist* **107**: 919–926.

Das, S. C. (1984) Resurgence of tea mosquito bug *Helopeltis theivora* Waterh, a serious pest of tea. *Two and a bud* **31(2)**: 36–39.

Devasahayam, S. and Nair, C. P. R. (1986) Tea mosquito bug on cashew in India. *Journal of Plantation Crops* **14(1)**: 1–101.

Dhandapani, N. and Balasubramanian, M. (1984) Life table studies of gram pod borer *Heliothis armigera* (Hubner) on tomato. *Indian Journal of Entomology* **46**: 447–451.

Green, E. E. and, (1901) *Helopeltis* what we know and what we want to know about it. *Circ. R. Bot. Gdn. Ceylon* **1 (21)**: 277–283. (cfzEntwistle, P.F.1972. Pests of Cocoa, 779p).

Hartley, J. C. and, (1965) The structure and function of the egg shell of *Deraeocoris ruber* L. (Heteroptera: Miridae). *J. Ins. Physiol.* **11**: 103–109.

Jeevaratnam, K. and Rajapakse, R. H. (1981) Biology of *Helopeltis antonii* Sign. (Heteroptera: Miridae) in Sri Lanka. *Entomon* **6(3)**: 247–251.

Lean, O. B. (1926) Observations on the life history of *Helopeltis* on cotton in Southern Nigeria. *Bulletin of Entomological Research* **16**: 319–324.

Mumford, J. D. and Norton, G. A. (1984) Economics of decision making in pest management. *Annual Review of Entomology* **29**: 157–174.

Pillai, G. B. and Abraham, V. A. (1974) *CPCRI Annual Report for 1973*, Kasargod, India.

Pillai, G. B., Singh, V. and Premkumar, T. (1976) *CPCRI Annual Reportfor 1975*, Kasargod, India.

Raj, D. (1992) Control of *Helopeltis* through cultural practices. *Tea Times* 3–7.

Rao, B. R. S. and Hayat, M. (1986) The chalcidoids of India and adjacent countries. *Oriental Insects* **20**: 184–207.

Rao, G. N. and Murthy, R. L. N. (1976) Economics of tea pest control. *Bulletin of UPASI Tea Scientific Department* **33**: 88–100.

Rattan, P. S. (1987) Economic threshold levels for *Helopeltis schoutedeni* (Mosquito bug), a major pest of tea in Malawi. *Quarterly Newsletter of tea Research Foundation (Central Africa)* **85**: 8–17.

Rau, A. S. (1940) *He lope ltis*. Miscellaneous Paper No. 2: 1–8., UPASI Tea Scientific Department.

Rhamhalinghan, M. (1987) Feeding behaviour of *Coccinella septempunctata* L. var. *confusa* Wiedemann (Coleoptera: Coccinellidae) in relation to temperature-I, Pre oviposition period. *Journal of Entomological Research* **11(2)**: 178–183.

Shaw, W. S. and, (1928) Observations on *Helopeltis* (Tea mosquitoblight) for South Indian Tea Planters;. *UPASI Sci. Bull. pp. 56.*

Sudhakar, M. A. (1975) Role of *Helopeltis antonii* (Hemiptera: Miridae) in causing scab on guava fruits, is biology and control.. *Mysore Journal of Agricultural Science* **9**: 205–206.

Sudhakar, M. A. (1976) Role of *Helopeltis antonii* (Hemiptera: Miridae) in causing scab on guava fruits, is biology and control Abstract of M.Sc. (Ag) Thesis. *Mysore Journal of Agricultural Science* **11**: 205–206.

Sundararaju, D. (1993) Studies on the parasitoids of tea mosquito bug, *Helopeltis antonii* Sign. (Heteroptera: Miridae) on cashew with special reference to *Telenomus* sp. (Hymenoptera: Scelionidae). *Journal of Biological Council* **7(1)**: 6–8.

Sundararaju, D. (1996) Studies on *Helopeltis* spp. with special reference to *H. antonii* Signoret in Tamil Nadu. *Ph.D. Thesis*, Tamil Nadu Agriculture University, Coimbatore, p. 202.

Way, M. J. and Khoo, C. (1989) Relationships between *Helopeltis theobromae* damage and ants with special reference to Malaysian cocoa smallholdings. *Journal of Plant Protection in Tropics* **6**: 1–11.

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Litter arthropod diversity and community structure in an evergreen forest in the Wayanad region of Western Ghats

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ABSTRACT: Patterns of seasonal variation in litter arthropod community diversity and trophic interrelationships in different litter layers associated with a wet evergreen rainforest of South Western Ghats in Wayanad are analyzed. Except for ptiliidae and collembolans significant seasonal and layer wise variation in the faunal species richness and abundance appeared negligible. Coleopterans, mites and ants were the most abundant taxa. Though the abundance of litter arthropods showed a peak during the post-rainy season, high diversity values (H^1) were recorded during southwest monsoon period, due to an increase in evenness (E_{var}) resulting from the reduction in the dominance of ptiliids and mites. Abundance of fungivorous psocoptera in the summer season and ptiliidae in the post-rainy season were noticed. Layer specific variation was noticed with fungivorous thrips and psocopterans dominating the fresh layer; and ants, mites and detritivores, in the fermentation and humus layers.

KEYWORDS: Litter arthropod diversity, trophic structure, wet evergreen forest, Western Ghats

INTRODUCTION

Litter fall in wet evergreen forests remains consistent as fresh litter is available throughout the year in comparison to deciduous and plantation forests with a more seasonal trend in litterfall (Ananthakrishnan, 1996). Litter invertebrates provide a good indication of ecological conditions because they are highly diverse and functionally important and can integrate a variety of ecological processes, besides being sensitive to environmental change (Greenslade and Greenslade, 1984; Brown, 1997). A lesser interest in below ground invertebrate communities is obviously due to the fact that litter fauna are locally very numerous, with a wide range of mobility requiring

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enormous sampling efforts and are often difficult to identify. Many of the studies are from temperate or tropical zones leaving a lacuna in observations from the resource rich subtropical forest habitats. In the light of the rapid destruction of tropical forests, it is imperative to survey the remaining areas as quickly as possible in order to prioritize ranges and submit biological data relevant to conservation and sustainable development alternatives in areas of human expansion (McNeely, 1995; Prance, 1995).

Lavelle *et al.* (1993) suggested that biological systems of regulation of organic matter turnover are most strongly expressed in moist tropical situations where optimal conditions of temperature and humidity remove the higher-level constraints of climate over biota. With a wide array of bioclimatic and topographic conditions, the Western Ghats, fringing the Arabian sea coastline of Indian peninsula has a high level of biodiversity and endemism and at the same time it is also a most threatened region due to various land practices and other development activities and has accordingly earned a status as one of the 25 biodiversity 'hotspots' (World Conservation Monitoring Center, 1992, Myers, 1988). The South Western Ghats montane rain forests are the most species rich ecoregion in the Deccan peninsula (WWF, 2001). Nearly three-fourths of the natural vegetation in the ecoregion has been cleared or converted, and the remaining severely fragmented forests are one of the major conservation priorities in a global scale due to their fragility, biological richness, high rates of endemism and multiple anthropogenic threats (Pascal, 1991). The Wayanad region of Western Ghats is a transitional zone from the moist *Cullenia* dominated forests in the South Western Ghats to the northern drier dipterocarp forests (Rodgers and Panwar, 1988). No litter insect diversity inventories were conducted in the evergreen forests in the Wayanad region of South Western Ghats that has considerable variation in plant diversity from the adjoining deciduous and semi evergreen forests of Wayanad. The presence of moist deciduous forests in the wet evergreen zone indicates their secondary nature after a possible degradation of original wet evergreen forests (Pascal, 1991). The objective of this work is to record the seasonal patterns of litter anthropod diversity and abundance in a selected tropical wet evergreen forest in Wayanad. It is expected that this analysis may provide the decision makers and conservation organizations a powerful tool in maximizing the impact of policies for the conservation of the remaining evergreen forests in the region.

MATERIALS AND METHODS

Study site

The fieldwork was carried out at Chanthanathode wet evergreen forests in the North Wayanad Western Ghats ecoregion (11° 45′N latitude and 11°58′N latitude and 75°50′ and 76°51′E latitude, 800 msl). Major litter contributing trees in the region are *Artocarpus hirsutus, Terminalia bellirica, Macaranga peltata, Embilica officinalis, Olea diocia, Nemedra elaeagnoidea, Lagerstroemia microcarpa, Schleichera oleosa. Mesua ferrea, Dalbergia latifolia, Cinnamomum malabatum, Xylia xylocarpa, Flacourtia cataphracta. Diospyros bourdillonii* and *Alstonia scholaris*. The undergrowth

consisted of canes, *Strobilanthes* sp. and ferns of *Allophylus* sp. Bulk of epiphytic vegetation is of mosses and lichens (Forests and Wildlife Department Working Plan, 2001).

Data collection

Twelve litter samples of 1 m^2 area, four of freshly fallen (L), fermentation (F) and humus (H) layer were collected during June–September (Southwest monsoon season), October–November (Northeast monsoon season), December–February (post-rainy season) and March–May (summer season) in 2002–03. Mean values of each season were taken to account for the abundance of individuals.

Fauna was extracted with a series of 15–20 cm diameter Berlese funnel fitted with 4–6 mm mesh screens and a 60 W light bulb for 1–2 days. Common names of the litter contributing trees were collected from the local forest office and the scientific names were from the KFRI handbook No. 17 (Sasidharan, 2004).

Collected fauna were sorted, counted and identified by the authors and by the specialists (see acknowledgment) and assigned to trophic level according to whether the majority of members of the taxon were predatory, detritivorous or fungivorous (Borror *et al.*, 1996). The specimens are curated temporarily at the research station and will eventually be deposited in the ZSI, Western Ghats regional station, Calicut.

DATA ANALYSIS

To understand the diversity patterns, alpha diversity indices (richness, evenness and diversity), dominance/diversity curves, rarefaction plot and rank abundance plot were considered.

Species or taxa richness expresses how many taxa/group (S) exists in the region studied; Evenness index was calculated with the new evenness index E_{var} of (Smith and Wilson, 1996) rated as best by Magurran (2003). It is based on the variance in abundance over the species,

$$E_{\text{var}} = 1 - [2/\pi \arctan({}^{S}\Sigma_{i=1}(\ln n_i - {}^{S}\Sigma_{j=1} \ln n_j/S)^2/S)]$$

arc tangent is assumed to provide an angle in radians. Variance is then converted by $-2/n$ arctangent () to a 0–1 range with 0 representing the minimum evenness and 1 the maximum, where n_i = the number of individuals in species i; n_j = the number of individuals in species j; and S = the total number of species in the sample (Magurran, 2003).

Shannon's diversity index (H′) was calculated with Estimate S software (version 6.0b1) (Colwell, 2000).

Dominance/diversity curves, displaying the relative abundances of the taxa within a community, have been constructed from field data (Whittaker, 1965). The criterion to be optimized in fitting curves is the minimization of the sum of squares of the deviation between the observed points and the ranked abundance fitted line (least sum of squares). Dominance/diversity curves were plotted and evenness index calculated using Gleason's software.

Rarefaction plot, a method for intrapolating smaller samples and estimating taxa richness in the rising part of the taxon-sampling curve (Colwell and Gotelli, 2001) was done using Biodiversity pro software (1997). Rank/abundance plot was plotted with relative abundance of each order against rank of taxa/order (Whittaker, 1965).

One-way ANOVA was used at relating the variations between the layers of different seasons. Anova model was applied to find out whether there is a statistically significant seasonal difference in the abundance of ptiliids and collembolans and also to determine the seasonal variations in faunal abundance between L, F and H layers with post rainy season as the standard variable for comparing seasonal means and humus layer as the standard variable for comparing layer wise means (Gujarati, 2003). Standards were taken on the basis of most abundant season/layers. The relationship between the trophic categories *viz.*, predators, detritivores and fungivores were analysed with Pearson's correlation. Statistical analysis was done with GRETL open source software version 0.93.

RESULTS

Eighteen litter arthropod faunal groups were recorded and their ranks based on relative abundance is represented in Fig. 1. Coleopterans, mites and ants were the most abundant taxa sampled, collectively accounting for 69% of the total individuals captured. The abundance of ptiliidae (Coleoptera) during the post-rainy season and psocoptera during the premonsoon season was noticeable.

Seasonal and layer wise abundance patterns

Coleoptera was the dominant group (35%) during the post-rainy season and southwest monsoon season (23%), followed by mites and ants. Mites (25%), coleoptera (21%) and psocoptera (13%) dominated during summer season. Fauna was evenly distributed during the northeast monsoon season.

Thysanoptera (20%) dominated the L layer during post-rainy, psocoptera (17%) in the premonsoon and mites during the southwest monsoon seasons. In the F layer mites dominated except for the domination of coleoptera during northeast monsoon season. Coleoptera represented mostly by ptiliids dominated the H layer throughout the study period (Fig. 2).

Litter arthropodal trophic structure

Predatory staphylinids and ants belonging to *Strumigenys* sp. fungivorous ptiliids and entomobryid collembolans were the dominant trophic categories through out the study period. Layer wise variation was noticed with fungivorous thrips and psocoptera dominating the L layer, ants, mites and detritivores in the F and H layers (Fig. 5, Fig. 2).

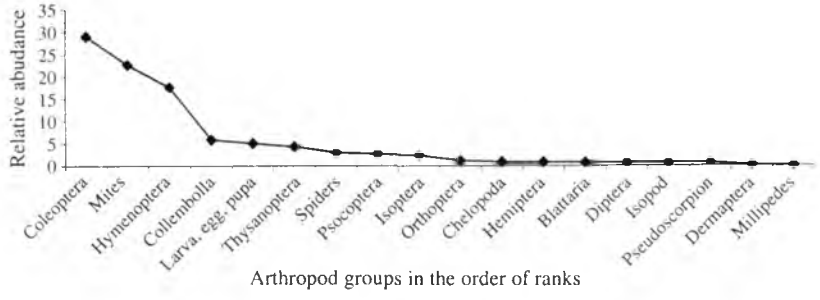

FIGURE 1. Relative abundance of litter arthropods plotted against the rank order (Whittaker's plot).

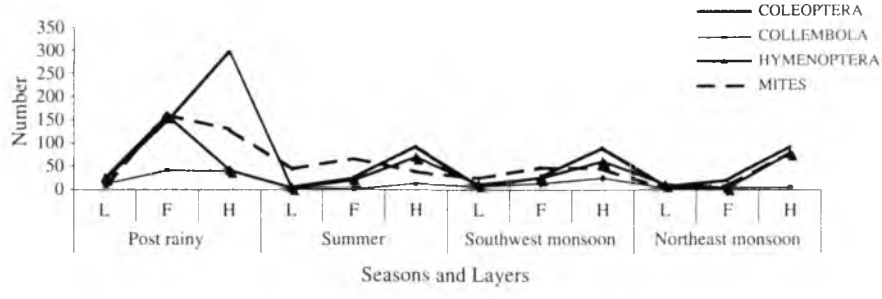

FIGURE 2. Seasonal dynamics in the abundance of dominant litter arthropods in the L, F and H litter layers.

Diversity and statistical analysis

Rank-abundance plot showed a shallower slope, implying that the litter arthropod faunal distribution is even during the study period, consistent with the lognormal or broken stick model (Magurran, 2003). Four models have been fitted on the rank abundance data with General log normal (0.9214) recording the best fit (i.e. lowest deviance) (Fig. 3).

Rarefaction plot showed high diversity values during southwest monsoon period. Rarefaction curve for the post-rainy season reached an asymptote indicating sampling is satisfactory for the period, whereas the curve (Fig. 4) for southwest monsoon period indicates further sampling is required. Shannon's diversity index value (H') and observed taxa richness (S) showed distinct seasonal and layer wise patterns. E_{var} showed a much less value for H layer indicating uneven distribution of individuals (Table 1).

Results of Anova model with abundance of taxa of post-rainy season as the standard variable (abundance is highest for this season) showed no significant effect of seasons on arthropod abundance. (Summer season $P = 0.125$, Southwest monsoon $P = 0.085$, Northeast monsoon period $P = 0.057$). Anova model for ptiliids and collembolans (Summer season $P = 0.001$, $P = 0.001$, Southwest monsoon season $P = 0.002$, $P = 0.025$, Northeast monsoon season $P = 0.004$, $P = 0.001$) showed

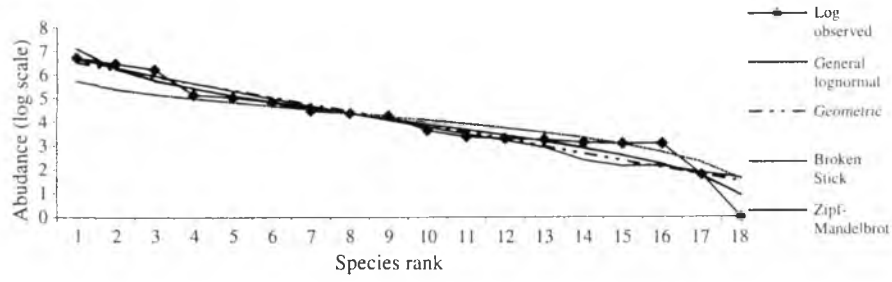

FIGURE 3. Fitted rank abundance curves for the litter faunal assemblage.

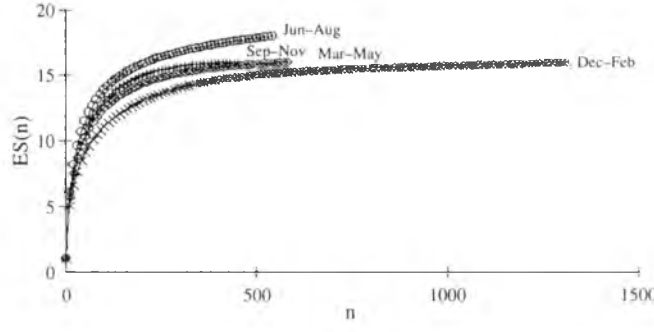

FIGURE 4. Rarefaction plot with expected number of orders $E_{s(n)}$ plotted on Y axis against abundance of individulas (n) on X axis.

TABLE 1. Seasonal and layer wise indices of abundance, Richness, Shannon's diversity and Evenness (E_{var}) indices.

Seasons	Abundance	Richness	Shannon's diversity index	Evenness (E_{var})
Post rainy	1312	16	1.86	0.221
Summer	581	16	2.08	0.282
Southwest monsoon	541	18	2.19	0.279
Northwest monsoon	457	16	2.05	0.335
Layers				
L	461	16	2.28	0.335
F	1014	15	2.01	0.336
H	1416	17	1.77	0.198

significant effect of seasons. The layer wise distribution of different taxa with H layer as the standard variable showed no significant effect of layers on abundance. (L Layer $P = 0.517$, F layer $P = 0.121$). One-way Anova showed no significant seasonal variation in the abundance of litter arthropods in L ($P = 0.3$) and H ($P = 0.6$) layers and variation was significant in F layer ($P = 0.01$). Pearson's correlation showed high

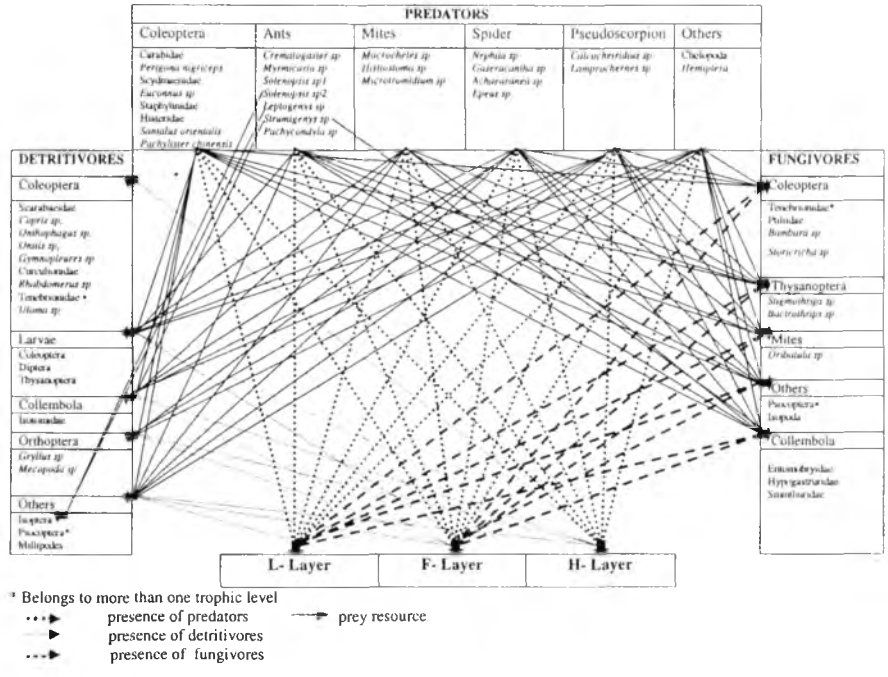

FIGURE 5. Trophic interrelationship of litter arthropod fauna in the evergreen forest.

degree of correlation between the abundance of predators and fungivores ($P = 0.006$) and no significant correlation with the abundance of detritivores ($P = 0.08$).

DISCUSSION

The forest floor litter insect faunal community structure and abundance associated with an evergreen forest litter habitat in the Western Ghats is recorded for the first time. Existing data on litter arthropod diversity is based on work in the moist and dry deciduous forests and plantation forests in the region (Ananthakrishnan *et al.*, 1993; Ananthakrishnan and Sabu, 1993; Sabu *et al.*, 1995). Significant differences in the faunal species richness, abundance and complexities during different seasons were absent in the study site except for ptiliids and collembolans, which might be related to the steady influx of litter in the evergreen forest. The results agree with the findings (Novotny and Basset, 1998) that the overall seasonality of fauna is distinctly lower in tropical than in temperate ecosystems and most of the tropical species are present throughout the year.

Abundance of fungivorous psocoptera during the summer and ptiliidae during the post rainy season were noticed. The presence of ptiliids as the dominant coleopteran fauna is obvious during the post-rainy season whereas, staphylinids and scarabaeids were the major coleopteran families in the adjacent deciduous forests (Vineesh *et*

al., 2003). The extensive wetness in the evergreen forests in general might have contributed to this observation. Coleoptera figured as the most abundant insect order due to the abundance of ptiliids in the habitat. During the southwest monsoon period, collembolan populations doubled compared to other summer months. This might be related to the preference of collembolans towards wetness (Swift *et al.*, 1979). Psocoptera increased during pre-monsoon months and their abundance is noted in L layer alone. Low abundance of termites when compared to the adjacent deciduous sites might be due to their better adaptability to environments with poor quality of organic resources and low quality of water (Decaens *et al.*, 1994). It might also be due to the inadequacy of the sampling methodology followed and the wet and moist nature of the study site.

Dominance of predatory and fungivorous insect fauna in the evergreen litter habitat indicates the high resource availability including fungal blooms and prey organisms. The parallel rise in the macroarthropod predator groups *viz.*, pseudoscorpions, spiders, ants, staphylinids and chelopods with fungivorous groups suggests the significance of latter in maintaining the diversity and abundance of predator faunal community in natural forest litter stands.

The fit of the general log normal distribution with the faunal abundance data is a feature of species rich communities (Whittaker, 1965; Hughes, 1986; Magurran, 2003). It could be asked whether anything is to be achieved by fitting models to dominance/diversity data since agreement with such a model does not support any particular ecological hypothesis. Pielou (1975) answers the question by pointing out that fitting models to dominance/diversity data leads to economy of description and facilitates comparison among different communities. These models are important ecological tools and their potential in elucidating empirical patterns of diversity has only just begun to be realized (Magurran, 2003).

The rarefaction curve for the post-rainy season reached an asymptote indicating sampling is satisfactory for the period, whereas the rarefaction curve for southwest monsoon period observed that further sampling is required for the period (Magurran, 2003). Even though the abundance values showed a peak during the post-rainy season, the high diversity value during southwest monsoon season is due to the even distribution of litter arthropod fauna during the period. Evenness index has a lower value during post rainy season due to the dominance of mites, coleopterans and ants.

Our sampling technique might have resulted in under representation of large, active species, such as many carabids, that were able to take evasive action during our approach. Again, we might have missed many insect larvae and other soft bodied ones and sources of error probably introduce a conservative bias in our richness and abundance counts. Still, it provides a glimpse of the arthropod faunal diversity enclosed within the wet evergreen litter ecosystem in the Wayanad forests. Some taxa *viz.*, psocoptera and many coleopteran families were abundant in the samples and could not be as thoroughly sorted or precisely identified as others.

Interpretation of studies such as this is compromised by difficulties in identification of species due to our incomplete knowledge of species diversity within speciose

but little-known taxa, our inability to identify larvae of many groups especially the coleoptera at lower taxonomic level. Obviously, more information needs to be gathered about biologies of the component taxa at various life stages in order to gain a more complete picture of how these assemblages interact.

ACKNOWLEDGEMENTS

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REFERENCES

Ananthakrishnan, T. N. (1996) *Forest Litter Insect Communities: Biology and Chemical Ecology*, Oxford & IBH: New Delhi.

Ananthakrishnan, T. N., Gopichandran, R. and Subramanian, V. R. (1993) Impact of chemical changes during decomposition of teak litter on the dynamics of natural insect communities at varying altitudes. *International Journal of Ecology and Environmental Sciences* **18**: 63–74.

Ananthakrishnan, T. N. and Sabu, K. Thomas (1993) Chemical ecology of two heterogenous forest litter ecosystem and related trophic interaction of insect communities. *International Journal of Ecology and Environmental Sciences* **19**: 143–160.

Borror, D. J., De Long, D. M. and Triplehon, C. A. (1996) *An Introduction to the Study of Insects*, Saunders Publication.

Brown, M. J. F. (1997) Effects of harvester ants on plant species distribution and abundance in serpentine grassland. *Oecologia* **112**: 237–243.

Colwell, R. K. (2000) Estimates: Statistical estimation of species richness and shared species from samples (Software and User's Guide), Version 6.0b.1. `http:viceroy.eeb.uconn.edu/estimates`.

Colwell, R. K. and Gotelli, N. J. (2001) Quantifying biodiversity: procedures and pitfalls in the measurement and comparison of species richness. *Ecology Letters* **4**: 379–391.

Decaens, T. P., Lavelle, J. J., Jimenesjaen, G., Escobar, and Rippstein, G. (1994) Impact of land management on soil macrofauna in oriental Llanos of Colombia. *European Journal of Soil Biology* **30**: 157–168.

Forests and Wildlife Department Working Plan (2001). North Wayanad Division, Forests and Wildlife Department, Government of Kerala, India.

Greenslade, P. J. M. and Greenslade, P. (1984) Invertebrates and environmental assessment. *Environment and Planning* **3**: 13–15.

Gujarati, D. N. (2003) *Basic Econometrics*, Mac Graw-Hill, Inc.

Holldobler, B. and Wilson, E. O. (1990) *The Ants*, Belknap Press of Harvard University Press: Cambridge, p. 732.

Hughes, R. G. (1986) Theories and models of species abundance. *American Naturalist* **128**: 897–899.

Lavelle, P., Blanchart, E., Martin, A., Spain, A. V., Toutain, F., Barois, I. and Scaefer, R. (1993) A hierarchial model for decomposition in terrestrial ecosystems: application to soils of humid tropics. *Biotropica* **25**: 135–150.

Magurran, A. E. (2003) *Ecological Diversity and its Measurement*, Princeton University Press: Princeton, New Jersey.

McNeely, J. A. (1995) Keep all the pieces: systematics 2000 and world conservation. *Biodiversity and Conservation* **4**: 510–19.

Myers, N. (1988) Threatened biotas: 'hotspots' in tropical forestry. *The Environmentalist* **8**: 1–20.

Novotny, V. and Basset, Y. (1998) Seasonality of sap sucking insects (Auehenorrhyncha, Hemiptera) feeding on Ficus (Moraceae) in a low land rainforest in New Guinea. *Oecologica* **115**: 514–522.

Pascal, J. P. (1991) Floristic composition and distribution of evergreen forests in the Western Ghats, India. *Paleobotanist* **39**: 110–126.

Pielou, F. C. (1975) *Ecological Diversity*, Wiley Interscience: New York, USA.

Prance, G. T. (1995) Systematics, conservation and sustainable development. *Biodiversity and Conservation* **4**: 490–500.

Rodgers, W. A. and Panwar, H. S. (1988) Planning a wildlife-protected areas network in India. Department of Environment. In: *Forests and Wildlife/Wildlife Institute of India Report*, Wildlife Institute of India: 1–2.

Sabu, K. Thomas, Jeyakumar, A. and Ananthakrishnan, T. N. (1995) Dynamics of insect communities at varying altitudes in the Shola forests of Kodaikanal hills, in relation to the chemical diversity of litter. *International Journal of Ecology and Environmental Sciences* **21**: 109–129.

Sasidharan, N. (2004) *Biodiversity Documentation for Kerala, Flowering Plants 6*, KFRI Handbook No. 17.

Shattock, S. O. and Barnett, N. J. (2001) *Australian Ants Online*, CSIRO: Australia.

Smith, B. and Wilson, J. B. (1996) A consumer's guide to evenness indices. *Oikos* **76**: 70–82.

Swift, M. J., Heal, O. W. and Anderson, J. M. (1979) *Decomposition in Terrestrial Ecosystems*, University of California Press: Los Angeles, USA.

Vineesh, P. J., Vinod, K. V, and Sabu, K. Thomas (2003) Litter arthropod dynamics and C:N values of deciduous forest all Thirunelli. In: *Proceedings of the STEC Sponsored National Seminar on Biodiversity Conservation and Participatory Forest Management*, 71–76.

World Conservation Monitoring Centre (WCMC), (1992) *Global Biodiversity*, Chapman and Hall: London.

Whittaker, R. H. (1965) Dominance and diversity in land plant communities. *Science* **147**: 250–260.

WWF website, (2001) Wild world, WWF full report, South Western Ghats montane rain forests (IMO151), Terrestrial Ecoregions. `www.worldwildlife.org`.

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Whitefly (Hemiptera: Aleyrodidae) fauna of Andaman and Nicobar Islands, India with description of a new species

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ABSTRACT: The whitefly fauna of Andaman and Nicobar Islands has been presented based on the collections made during April 2001. One new species, *Africaleyrodes orientalis*, has been described and illustrated. A total of 20 species have been observed far from these Islands. Ten species viz., *Aleurocanthus spiniferus, Aleuroclava psidii, Aleurolobus azadirachtae, Aleurolobus musae, Aleuroplatus alcocki, Aleurotrachelus saklespurensis, Dialeuropora decempuncta, Minutaleyrodes minutus, Pealius spina* and *Singhius morindae* are recorded for the first time from these islands.

KEYWORDS: Aleyrodidae, Andaman and Nicobar, whiteflies

INTRODUCTION

Andaman and Nicobar, popularly known as the emerald Isles, are spread in 8,249 sq. km area. They lie in the Bay of Bengal, approximately 1,220 km south east of the coast of West Bengal and 1,190 km east of Chennai (India: Madras). Among the insect fauna, the family Aleyrodidae (Insecta: Hemiptera) is little known from these Islands. Bhumannavar *et al.* (1991) while reporting on the insects of agricultural importance mentioned four species of aleyrodids viz., *Aleurocanthus woglumi* (Ashby) on *Citrus medica* and *Citrus reticulata, Dialeurodes kirkaldyi* (Kotinsky) on *Jasminum sambac, Neomaskellia bergii* (Signoret) on sugarcane (*Saccharum officinarum*) and *Trialeurodes ricini* (Misra) on *Moringa oleifera*. In the early 1900s, David identified the specimens received from the Central Institute for Agricultural Research, Port Blair

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as *Bemisia tabaci* (Gennadius). David and Jesudasan (2002) described a new species *Aleurocanthus musae* from *Musa* sp. and recorded occurrence of *Asialeyrodes indica* Sundararaj and David on *Ervatomia coronaria* from Andaman Nicobar Islands. Based on material collected during April 2001, this paper presents further species that have been identified. The specimens are presently in the collections of BVD.

MATERIAL AND METHODS

The study of the diversity of the aleyrodid fauna of Andaman is based on the material collected during survey conducted in different Islands of Andaman and Nicobar by David during April 2001. The whitefly infested leaves were collected from the host plants and the best mounts of puparia were obtained from which adults have emerged. The identities of whiteflies were established based on the study of the characteristic features of the puparial cases.

RESULTS AND DISCUSSION

During the present study of the aleyrodid fauna of Andaman and Nicobar Islands a total of 45 specimens were mounted representing 20 species under 17 genera in which one species belonging to *Alfricaleyrodes* has been determined new to science. Ten species viz., *Aleurocanthus spiniferus, Aleuroclava psidii, Aleurolobus azadirachtae, Aleurolobus musae, Aleuroplatus alcocki, Aleurotrachelus saklespurensis, Dialeuropora decempuncta, Minutaleyrodes minutes, Pealius spina* and *Singhius morindae* are recorded for the first time from these Islands. David (1993) synonymised *Aleuroplatus ficusgibbosae* (Corbett) with *Aleuroplatus alcocki* (Peal) in his monograph on Whitefly of Sri Lanka. However, this species was synonymised with *Aleuroplatus pectiniferus* (Quaintance and Baker) by Martin (1999). The record of 10 species including the new species raises the total aleyrodid fauna known from these Islands to 20.

1. *Aleurocanthus musae* David and Jesudasan

Aleurocanthus musae David and Jesudasan 2002. *Entomon* **27**(3): 323–325.

Material examined

India: Andaman and Nicobar Islands, *Musa* sp., 25.iv.2001, Coll: B. V. David. Holotype and three paratypes.

Host plant

Musa sp. (David and Jesudasan, 2002).

Distribution

India: Andaman and Nicobar Islands (David and Jesudasan, 2002).

2. *Aleurocanthus spiniferus* (Quaintance)

Aleurocanthus spiniferus (Quaintance), 1903. *Canadian Ent.* **35**: 63–64.
Aleurocanthus spiniferus: Quaintance and Baker, 1914. *U. S. D. A. Bur. Ent. Tech. Ser.*, **27**: 102.
Aleurocanthus rosae Singh, 1931. *Mem. Dep. Agric. India* **12(1)**: 70.
Aleurocanthus spiniferus: David and Subramaniam, 1976. *Rec. Zool. Surv. India*, **70**: 153.

Material examined

One puparium on *Streblus* sp., Havelock Island (Andaman and Nicobar Islands), 22.iv.2001, Coll: B. V. David.

Host plants

Citrus sp. (Usman and Puttarudraiah, 1955), *Rosa* sp. (Singh, 1931); *Vitis vinifera* (David and Subramaniam, 1976); *Streblus* sp. (new host record).

Distribution

Widespread throughout India (Jesudasan and David, 1991).

3. *Aleurocanthus woglumi* (Ashby)

Aleurocanthus woglumi (Ashby): Quaintance and Baker. *Proc. U. S. Natn. Mus.* **51**: 336, 355.

This species was observed on *Citrus medica* and *C. reticulata* in Andaman & Nicobar Islands by Bhumannavar *et al.* (1991).

Host plants

Citrus sp. (Hussain and Khan, 1945); *Achras zapota* (Rao and Rao, 1962); *Morinda tinctoria* and *Murraya koenigii* (David and Subramaniam, 1976), *Citrus medica* and *C. reticulata* in Andaman & Nicobar Islands by (Bhumannavar *et al.*, 1991).

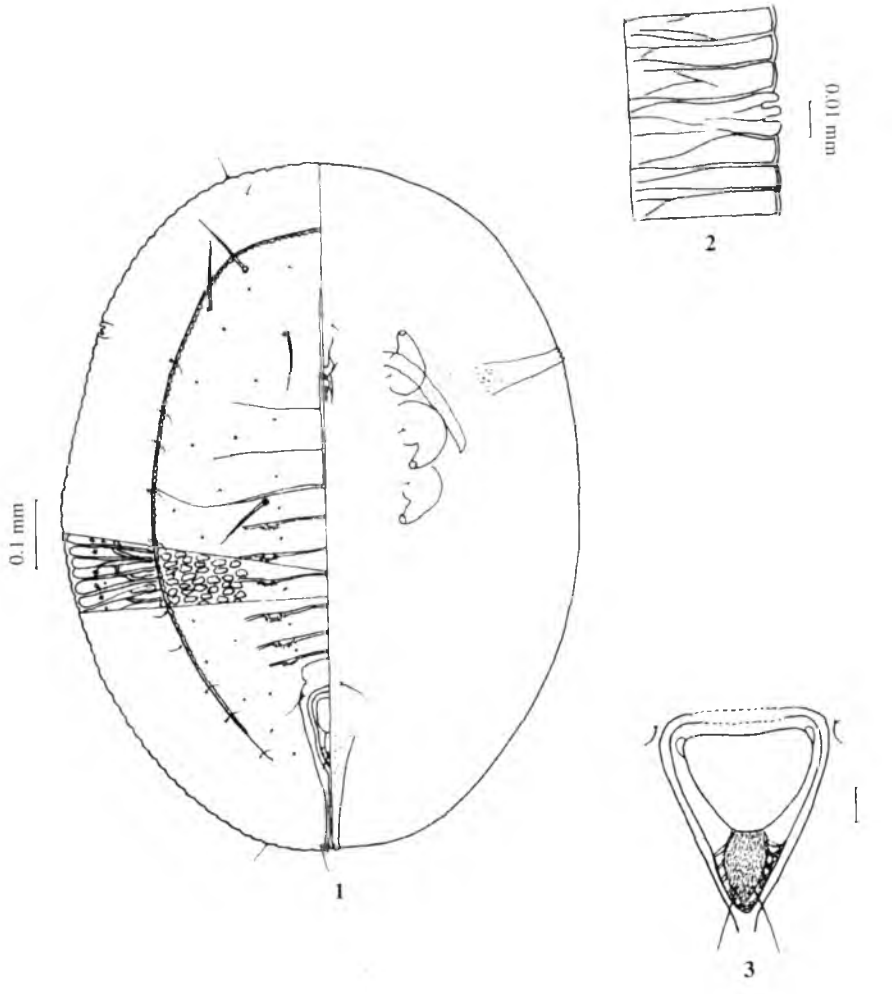
Distribution

India: Tamil Nadu (Coimbatore, Yercaud); throughout India (Jesudasan and David, 1991); Andaman and Nicobar Islands.

4. *Africaleyrodes orientalis* sp. nov.

Pupal case

White, with secretion of white wax; oval, male 1.20–1.22 mm long and 0.81–0.91 mm wide and female 0.81–0.90 mm long and 0.68–0.70 mm wide; widest across first abdominal segment region (Fig. 1); found singly 2–3 per leaf on the under surface of leaves.



FIGURES. *Africaleyrodes orientalis* David and Dubey sp. nov. 1. Pupal case; 2. Thoracic tracheal pore; 3. Vasiform orifice.

Margin

Crenulate, 6–7 crenulations in 0.1 mm. Thoracic and caudal tracheal pore regions differentiated from margin by three blunt teeth. Anterior and posterior marginal setae respectively, 26 and 46 μm long (Fig. 2).

Dorsal surface

Dorsum with four pairs of setae each with distinct bases, cephalic setae 20 μm long, first abdominal setae 17 μm long, eighth abdominal setae 18 μm long and

caudal setae on caudal furrow 32 μm long. Submargin separated from dorsal disc by well-defined submarginal furrow which is incomplete and not reaching to caudal ridge and inner margin is crenulate. Subdorsum with two pairs of setae on anterior cephalic region, 45–64 μm long and 10 pair of hook-like setae on submargin near submarginal furrow, sometimes on subdorsum, 6–18 μm long, a pair of minute setae on cephalic submargin, 6 μm long. Submarginal lines branched, submargin with a row of elliptical-shaped minute pores. Subdorsum tessellated. Submedian pockets with depressions present in all the segment sutures. Longitudinal moulting suture reaching margin and transverse moulting suture cauded, curved and reaching submarginal furrow. Median length of VII abdominal segment shorter than VIII. Pores and porettes scattered throughout dorsum. Pockets discontigous (Fig. 1).

Vasiform orifice

Trilobed, 90–114 μm long and 60–64 μm wide; operculum subtrapezoidal, 50–54 μm long and 32–40 μm wide, filling three-fourths of vasiform orifice. Lingula trilobed, spinose and included. A pair of long hair-like setae present on lingula, 38 μm long, Inner wall of vasiform orifice usually with four to five pairs of carinae (Fig. 3).

Ventral surface

Paired ventral abdominal setae 36 μm long and 67 μm apart. Minute setae at base of rostrum, 20 μm long. A pair of minute setae at base of pro- and mesothoracic legs, 8 μm long and metathoracic legs 9 μm long. Tracheal folds with spinules, spinules absent on tracheal submarginal regions, spinules extending beyond the prothoracic legs. Submarginal ventral fold distinct. Antennae vary in length, 94 μm long in male, reaching base of prothoracic legs and 148 μm long in female reaching base of metathoracic legs (Fig. 1).

Host plant

Unidentified.

Holotype

One puparium, on unidentified plant, Port Blair (Andaman and Nicobar Island), India, 24.iv.2001, Coll: B. V. David. Deposited in the collections of the Division of Entomology, Indian Agricultural Research Institute, New Delhi.

Paratypes

Thirteen puparia on slides, bearing the details of holotype. (Presently with BVD).

Remarks

This species resembles *Africaleyrodes indicus* Regu and David in shape, in characters of margin and in the structural details of vasiform orifice but distinct from it by the presence of first abdominal setae and by the presence of first abdominal setae and two pairs of long subdorsal setae on anterior cephalic region.

This species exhibits two kinds of submarginal setae (short and hook) in the same puparium.

Etymology

Derived from the collection region viz., Oriental region.

5. *Aleuroclava psidii* (Singh)

Aleurotuberculatus psidii Singh, 1931. *Mem. Dep. Rep. India*, **12(1)**: 61.
Aleuroclava psidii: Takahashi, 1932. *Rep. Dep. Agric. Govt. Res. Inst. Formosa*, **59**: 20.
Aleuroclava Singh: David and Subramaniam, 1976. *Rec. Zool. Surv. India*, **70**: 172.
Aleurotrachelus psidii Martin, 1999. CSIRO Entomology Technical Paper **38**: 31.

Material examined

Three puparia on *Psidium guajava*, Port Blair (Andaman and Nicobar), 20.iv.2001, Coll: B. V. David.

Host plants

Psidium guajava (Singh, 1931).

Distribution

India: Bihar (Pusa) (Singh, 1931); Andhra Pradesh (Himayatnagar, Begumpet) (Rao, 1958); throughout Tamil Nadu (David and Subramaniam, 1976), Andaman and Nicobar Islands (new distribution record).

6. *Aleurolobus azadirachtae* Regu and David

Aleurolobus azadirachtae Regu and David (1993). *Fippat Entomology Series*, **4**: 18.

Material examined

One puparium on unidentified plant, Port Blair (Andaman and Nicobar Islands), 20.iv.2001, Coll; B. V. David, one puparium, Wandoor, unidentified plant, 25, iv. 2001), Coll. B. V. David; 5 species on *Streblus asper* Harlock Islands. 25.iv. 2001, Col. B. V. David.

Host plants

Azadirachta indica, Holoptelia sp., *Lagerstroemia* sp. (Regu and David, 1993).

Distribution

India: Tamil Nadu (Padappai, Thirparappu), Kerala (Ambalamedu) (Regu and David, 1993); Andaman and Nicobar Islands (new distribution record).

7. *Aleurolobus musae* Corbett

Aleurolobus musae Corbett, 1935. *J. fed. Malay St. Mus.* **17**: 820–821.
Aleurolobus musae Corbett: Regu and David, 1993, *Fippat Entomology Series*, **4**: 31.

Material examined

One puparium on *Annona* sp., Port Blair (Andaman and Nicobar Islands), 20.iv.2001, Coll: B. V. David; five puparia on *Tamarindus indica* (new host records).

Host plants

Musa paradisiaca (Regu and David, 1993), *Annona* sp., *Tamarindus indica* (new host records).

Distribution

India: Tamil Nadu: Kunathoor, Coimbatore (Regu and David, 1993), Andaman and Nicobar (new distribution record).

8. *Aleuroplatus alcocki* (Peal)

Aleuroplatus alcocki Peal, 1903. *J. Asiat. Soc. Bengal*, **72**: 74–78.
Aleuroplatus ficusgibbosae Corbett, 1926. *Bull. Ent. Res.* **16**: 267–284. (Synonymised by David, 1993).
Aleuroplatus buchananiae Jesudasan and David, 1991. *Oriental Inst.*, **25**: 231–434. (Synonimised by Martin, 1999)
Aleuroplatus cinnamomi Jesudasan and David, 1991. *Oriental Inst.*, **25**: 231–434. (Synonimised by Martin, 1999)
Aleuroplatus distinctus Jesudasan and David, 1991. *Oriental Inst.*, **25**: 231–434. (Synonymised by Martin, 1999).
Aleuroplatus pectinserratus Singh: Martin, 1999. *CSIRO Entomoly Technical Paper* **38**: 38–39. (Synonymised by Martin, 1999).
Aleuroplatus walayarensis Jesudasan and David, 1991. *Oriental Inst.*, **25**: 231–434. (Synonymised by Martin, 1999).

Material examined

Six puparia on *Syzygium* sp., Port Blair (Andaman and Nicobar Islands), 20.iv.2001, Coll: B. V. David.

Host plants

Terminalia sp. (Singh, 1945); *Terminalia belerica, Casearia esculenta, Cinnamomum* sp., *Bauhinia lanzan* (Jesudasan and David, 1991); *Annona* sp., *Syzygium* sp. (new host records).

Distribution

India: Tamil Nadu: Tambaram, Kallar (The Nilgiris), Burliar; Kerala: Walayar (Jesudasan and David, 1991), Andaman and Nicobar (new distribution record).

9. *Aleurotrachelus saklespurensis* Regu and David

Aleurotrachelus saklespurensis Regu and David, 1992. *Entomon.* **17(1&2)**: 135–136.

Material examined

One puparium on *Bamboo* sp., Apringang (Andaman and Nicobar Islands), 25.iv.2001, Coll: B. V. David.

Host plants

Dimocarpus longon (Regu and David, 1992); *Bamboo* sp., (new host record).

Distribution

India: Saklespur (Regu and David, 1992), Andaman and Nicobar (new distribution record).

10. *Asialeyrodes indica* Sundararaj and David

Asisleyrodes indica Sundararaj and David. 1991. *J. Bombay Nat. His. Soc.*, **88**: 413.

Material examined

Five puparia on *Ervatomia coronaria*, 25.iv.2001, Wandoor (Andaman and Nicobar Islands), Coll: B. V. David.

Host plant

Ervatomia coronaria (Sundararaj and David, 1991).

Distribution

India: Maharashtra (Mumbai) (Sundararaj and David, 1991); Andaman and Nicobar Islands (new distribution record).

11. *Bemisia tabaci* (Gennadius)

Aleyrodes tabaci Gennadius, 1889. *Ellenike Georgia* (Greek Agriculture) (Athens), **5**: 1–3.

Aleurodes inconspicus Quaintance, 1900, *U. S. D. A. Bur. Ent. Tech. Bull.*, **8**: 28. (Synonymised by Russell, 1957: 122).

Bemisia emiliae Corbett, 1926. *Bull. Ent. Res.*, **16**: 273. (Synonymised by (Mound and Halsey 1978).

Bemisia tabaci (Gennadius) Takahashi, 1936. *Acta Entomologica*, **1**: 110.

Material examined

One puparium on *Phyllanthus* sp., Port Blair (Andaman and Nicobar Islands), 21.iv.2001, Coll: B.V. David; three puparia on *Acalypha indica*, Port Blair (Andaman and Nicobar Islands), 26.iv.2001, Coll: B. V. David; three pupariaon on *Colocasia* sp., Garacharma (Andaman and Nicobar Islands), 25.iv.2001, Coll: B. V. David.

Host plants

Abelmoschus esculentus, Achyranthes aspera, Brassica campestris, Brassica oleracea, Citrullus colocynthus, Cleome viscosa, Clerodendron infortunatum, Corchorus trilocularis, Cucumis melo, Euphorbia pilulifera, Gossypium sp., *Lannia asplenifolia, Lippia geminata, Nyctanthes arbortristis, Physalis peruviana, Solanum melongena, Solanum tuberosum, Solanum xanthocarpum, Trevia nudiflora, Trichosanthes dioica* (Misra and Singh, 1929); *Saccharum, officinarum* (Usman and Puttarudraiah, 1955); *Acalypha indica, Aristolochi bilabiosa, Datura fastuosa, Gauzuma tomentosa, Ipomoea cairica, Lantana camra, Macuna cochinchinensis, Morinda tinctoria, Ocimum sanctum, Phyllanthus fraternus, Rhynchosia minima* (David and Subramaniam, 1976); *Phyllanthus* sp., *Colocasia* sp. (new host records).

Distribution

Widely distributed in India (Jesudasan and David, 1991); Andaman and Nicobar Islands (new distribution record).

12. *Dialeurodes kirkaldyi*: (Kotinsky)

Aleurodes kirkaldyi Kotinsky, 1907. *Bull. Bd. Commnrs. Agric. For Hawaii. Dev. Ent.*, **2**: 95.

Dialeurodes kirkaldyi: Quaintance and Baker, 1914. *U. S. D. A. Bur. Ent. Tech. Ser.*, **27**: 98.

Dialeurodes kirkaldyi: Priesner and Hosny, 1934. *Bull. Minist. Agric. Egypt Tech. Scient. Serv.*, **139**: 2.

Dialeurodes kirkaldyi: David and Subramaniam, 1976. *Rec. Zool. Surv. India*, **70**: 133–233.

Material examined

Six puparia on *Jasminum* sp., Port Blair (Andaman and Nicobar Islands) 21.iv.2001, Coll: B. V. David.

Host plants

Jasminum auriculatum (David, 1958). *J. sambac, J. sessilifloum, Morinda citrifolia, M. tinctoria, Plumeria rubra, Ichnocarpus frutescens, Sarcostigma klenii* (Sundararaj and David, 1992); *Jasminum* sp.

Distribution

India: Throughout Tamil Nadu (Coimbatore) (David and Subramaniam, 1976); Maharashtra (Pune) (Jesudasan and David, 1991); West Bengal (Calcutta), Karnataka (Mysore); Kerala (Trivandrum) (Sundararaj and David, 1992); Andaman and Nicobar Islands (new distribution record).

13. *Dialeuronomada ixorae*: (Singh)

Dialeurdes ixorae Singh; 1931. *Mem. Dept. Agric. India, Ent. Ser.* **12**: 38.
Dialeurodes ixorae: David and Subramaniam, 1976. *Rec. Zool. Surv. India.*, **70**: 191–192.
Dialeuronomada ixorae (Singh). Sundararaj and David, 1991. *Hexapoda.* **3** (1&2): 27–47.
Dialeuronomada ixorae (Singh). Dubey & Sundararaj. 2004. *Formosan Entomol.*, **24**: 147–157.

Material examined

Eleven puparia on four slides on *Ixora* sp., Port Blair (Andaman Nicobar Islands), 21.iv.2001, Coll. B. V. David.

Host plants

Ixora coccinea (Singh, 1931); *Mumusops hexandra* (Rao 1958), *Tarenna asiatica, Aporosa lindleana, Antidesma acidum* (Sundararaj and David, 1991), *Atalantia monophylla, Archronycha zeylanicum*, (Meganathan and David, 1994), *Flemingia macrophyla, Olea dioica* (Dubey and Sundararaj, 2004).

Distribution

India: Tamil Nadu (Singh, 1931); Tanjore, Munchirai, Pechiparai (Sundararaj and David, 1991); Andhra Pradesh: Hyderabad (Rao, 1958); Karanataka: Jog falls, Gokarna, Kudremuch National Park (Dubey and Sundararaj, 2004); Andaman and Nicobar Islands (new distribution record).

14. *Dialeuropora decempuncta* (Quaintance & Baker)

Dialeurodes (Dialeuropora) decempuncta Quaintance and Baker, 1917. *Proc. U. S. Natn. Mus.*, **51**: 434.

Dialeuropora decempuncta (Quaintance and Baker), 1934. Takahashi, *Rep. Dep. Agric. Govt. Res. Inst. Formosa*, **63**: 46.

Dialeuropora decempuncta (Quaintance and Baker): David and Subramaniam, 1976. *Rec. Zool. Surv. India*, **70**: 196–197.

Material examined

Six puparia on *Annona* sp., on one slide Port Blair (Andaman and Nicobar Islands), 21.iv.2001, Coll: B. V. David.

Host plants

Annona squamosa, Dalbargia sisoo, Ficus religiosa, Morsus sp., Prunus sp., Streblus asper (Singh, 1931); *Annona cherimolia, Cordia myxa, Euphorbia pilulifera, Rosa* sp., (Rao, 1958); *Annona reticulata, Polyalthia longifolia* (David and Subramaniam, 1976); *Annona* sp.

Distribution

India: Bihar (Pusa), Uttar Pradesh (Lucknow) (Singh, 1931); Andhra Pradesh (Hyderabad) (Rao, 1958); throughout Tamil Nadu (David and Subramaniam, 1976); Maharashtra (Kandla, Chembur, Karnala and Mahableshwar); Karnataka (Bangalore); Kerala (Ambalamedu) (Sundararaj, 1989); Andaman and Nicobar Islands (new distribution record).

15. *Minutaleyrodes minutus* (Singh)

Dialeurodes minuta Singh, 1931. *Mem. Dep. Rep. Agric. India Ent. Ser.*, **12**(1): 42–43.

Aleurotuberculatus minutus (Singh): Takahashi, 1934. *Rep. Dep. Agric. Govt. Res. Inst. Formosa*, **63**: 50.

Aleurotuberculatus minutus (Singh): David, 1977. *Entomon*, **2**: 90.

Minutaleyrodes minutus (Singh): Jesudasan and David, 1991. *Oriental Ins.*, **25**: 314.

Material examined

One puparium on *Ixora coccinea*, Wandoor (Andaman and Nicobar Islands), 24.iv.2001, Coll: B. V. David; one puparium on *Ixora* sp., Port Blair (Andaman and Nicobar Islands), 24.iv.2001, Coll: B. V. David.

Host plants

Ixora sp. (Singh, 1931); *Ixora coccinea* (David, 1977).

Distribution

India: Bihar (Pusa) (Singh, 1931); Tamil Nadu (Chennai) (David, 1977); Maharashtra (Vashi) (Sundararaj, 1989); Andaman and Nicobar (new distribution record).

16. *Neomaskellia bergii* (Signoret)

Aleyrodes bergii Signoret. 1868. *Soc. Ent. France, Ann.* IV, **8**: 395.
Neomaskellia bergii Signoret: Quaintance and Baker. 1914. *U. S. D. A. Bur. Ent. Tech. Ser.* **27**(2): 104.

This species has been reported from Andaman & Nicobar Islands as occurring on sugarcane by Bhumannavar *et al.* (1991).

Host plants

Saccharum officinarum, Sorghum vulgare (Singh, 1931); *Cenchrus ciliaris* and *Setaria italica* (David and Subramaniam, 1976), *S. officinarum* in Andaman & Nicobar Islands (Bhumannavar *et al.*, 1991).

Distribution

Throughout India (David and Subramaniam, 1976).

17. *Pealius spina* (Singh)

Pealius spina Singh, 1931. *Mem. Dep. Agric. India*, **12**(1): 27.
Aleuroplatus spinus: Takahashi, 1952. *Mushi*, **24**: 23.
Pealius spina: David and Subramaniam, 1976. *Rec. Zool. Surv. India*, **70**: 209.

Material examined

Three puparia on *Ficus religiosa*, Port Blair (Andaman and Nicobar), 24.iv.2001, Coll: B. V. David.

Host plants

Ficus religiosa (Singh, 1931).

Distribution

India: Bihar (Mirpur Khas, Daulatpur) (Singh, 1931); Tamil Nadu (Salem) (David and Subramaniam, 1976); Padappai (Jesudasan and David, 1991); Andaman and Nicobar (new distribution record).

18. *Singhius morindae* Sundararaj and David

Singhius moridae Sundararaj and David, 1994. *J. Bombay Nat. Hist. Soc.* **89**: 103-104.

Material examined

Four puparia on *Phyllanthus reticulatus*, Port Blair (Andaman and Nicobar Islands), 21.iv.2001, Coll: B. V. David.

Host plants

Morinda tinctoria (Sundararaj and David, 1994), *Phyllanthus reticulatus* (new host record).

Distribution

India: Tamil Nadu (Vellimalai) (Sundararaj and David, 1994); Andaman and Nicobar Islands (new distribution record).

19. *Trialeurodes ricini* (Misra)

Aleyrodes ricini Misra. 1923. *Proc. 5th Ent. Mtg. Pusa.*, 129–135.
Trialeurodes ricini (Misra) Singh, 1931. *Mem. Dept. Agric. India, Ent. Ser.* **12**(1): 46.

Bhumannavar *et al.* observed it on *Moringa oleifera* in Andaman and Nicobar Islands (Bhumannavar *et al.*, 1991).

Host plants

Achras zapota, Breynia rhamnoides, Ricinus communis (Singh, 1931): *Euphorbia* sp., *Murraya koenigii, Phyllanthus* sp., *Rosa* sp., (Rao, 1958), *Anonna glabra* and *Gossypium hirsutum* (David and Subramaniam, 1976).

Distribution

India: Bihar (Pusa); Maharashtra (Nadiad, Bhagalpur); Gujarat (Broda) (Singh, 1931); Andhra Pradesh (Hyderabad); (Rao, 1958); Tamil Nadu (Coimbatore, Chennai) (David and Subramaniam, 1976); Andaman and Nicobar Islands (new distribution record).

20. *Vasdavidius indicus* (David and Subrmaniam)

Aleurocybotus indicus David and Subramanium, 1976. *Rec. Zool. Surv. India*, **70**: 157: 159.
Vasdavidius indicus (David and Subramanium) Russell, 2000. *Proc. Entomol. Soc. Washington*, **102**(2): 374–383.

Material examined

Three puparia on *Chloris barbata*, Port Blair (Andaman and Nicobar Island), 21.vi.2001, B. V. David.

Host plants

Chloris barbata (David and Subramaniam, 1976).

Distribution

India: Tamil Nadu: Coimbatore (David and Subramaniam, 1976); Andaman and Nicobar Islands (new distribution record).

REFERENCES

Bhumannavar, B. S., Mohanraj, P., Ranganath, H. R., Jacob, T. K. and Bandyopadhayay, A. K. (1991) Insects of agricultural importance in Andaman and Nicobar Islands. In: *Research Bulletin*, Central Agricultural Research Institute: Port Blair 744101, **6**: p. 49.

David, S. K. (1958) Insects and mites affecting Jasmine in the Madras State. *Madras Agric. J.* **45(4)**: 146–150.

David, (1977) A new species of *Aleurotuberculatus* Takahashi and redescription of *Aleurotuberculatus minutus* (Singh) (Aleyrodidae, Hemiptera). *Entomon* **2**: 89–92.

David, B. V. (1993) The whitefly of Sri Lanka (Homoptera: Aleyrodidae). *Fippat Entomology Series* **3**: 1–32.

David, B. V. and Jesudasan, R. W. A. (2002) A new species of *Aleurocanthus* and *Asialeyrodus indica* Sundararaj and David (Aleyrodidae: Homoptera) from Andaman Nicobar Islands. *Entomon* **27**: 323–325.

David, B. V. and Subramaniam, T. R. (1976) Studies on some Indian Aleyrodidae. *Rec. Zool. Surv. India* **70**: 133–233.

Dubey, A. K. and Sundararaj, R. (2004) A review of the genus *Dialeuronomada* Quaintance and Baker (Hemiptera: Aleyrodidae) with description of two new species. *Formosan Entomol.* **24**: 147–157.

Hussain, M. A. and Khan, A. W. (1945) The Citrus Aleyrodidae (Homoptera) in Punjab and their control. *Mem. Entomol. Soc. India* **1**: 1–41.

Jesudasan, R. W. A. and David, B. V. (1991) Taxonomic studies on Indian Aleyrodidae (Insecta: Homoptera). *Oriental Ins.* **25**: 231–434.

Misra, C. S. and Singh, K. (1929) The cotton whitefly (*Bemisia gossypiella* n. sp.). *Bull. Agric. Res. Inst. Pusa* **196**: 1–7.

Martin, J. H. (1999) The whitefly fauna of Australia (Sternorrhyncha: Aleyrodidae). *CSIRO Ento. Tech. Paper No.* **38**: 1–197.

Meganathan, P. and David, B.V. (1994) Aleysiodid fauna (Aleyrodidae: Homoptera) of Silent Valley, a tropicala evergreen, rain-forest in Kerala, India. *FIPPAT Entomological Series* **No. 5**: 1–83.

Rao, A. S. (1958) Notes on Indian Aleyrodidae with special reference to Hyderabad. *Proc. 10th Int. Congre. Ent.* **1**: 331–336.

Rao, R. N. and Rao, B. H. K. (1962) *Final report of the scheme for biology and control of whiteflies, Rajendranagar, for the period 8.2.1960 to 31.3.1962*, Andhra Pradesh, Department, Agric.: Andhra Pradesh, Hyderabad, p. 20.

Regu, K. and David, B. V. (1992) A new whitefly *Aleurotracheles saklespurensis* sp. nov. (Aleyrodidae: Homoptera) from India. *Entomon* **17**: 135–136.

Regu, K. and David, B. V. (1993) Taxonomic studies on Indian Aleyrodids of the tribe Aleurolobini (Aleyrodinae: Aleyrodidae: Homoptera). *FIPPAT Entomological Series* **4**: 1–79.

Singh, K. (1931) A contributions towards our knowledge of the Aleyrodidae (whiteflies) of India. *Mem. Dept. Agric. India Ent. Ser.* **12**: 1–98.

Singh, K. (1945) Notes on Aleurodidae from India III. *India J. Entomol.* **6**: 75–78.

Sundararaj, R. (1989) Taxonomic studies on Indian Aleyrodids of the tribe Dialeurodini (Aleyrodidae: Homoptera) *Ph.D. Thesis*, University of Madras, p. 171–submitted.

Sundararaj, R. and David, B. V. (1991) On the general *Asialeyrodes* Corbett and *Cockerelliella* gen. Nov. from India. *J. Bombay Nat. Hist. Soc.* **88**: 415–424.

Sundararaj, R. and David, B. V. (1991b) Ten new species of *Dialeunomada* Quaintance & Backer (Homoptera: Aleyrodidae) from India. *Hexapoda* **3**: 27–47.

Sundararaj, R. and David, B. V. (1992) Host correlated variation *Dialeurodes kirkaldyi* (Kotinsky) (Aleyrodidae: Homoptera: Insecta). *Hexapoda* **4**: 33–38.

Sundararaj, R. and David, B. V. (1994) On a new species of *Singhius* Takahashi (Aleyrodidae: Homoptera) with a key to Indian species. *J. Bombay Nat. Hist. Soc.* **89**: 103–104.

Usman, S. and Puttarudraiah, M. (1955) A list of the insects of Mysore including the mites. *Dept. Agric. Ent. Ser. Bull.* **16**: 1–194.

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Diversity of terrestrial insects in a cultivated land of tarai region of Kumaun, Uttaranchal

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ABSTRACT: Species richness, population density and biomass, species diversity, secondary production and herbivory of terrestrial insects in a cultivated land of tarai region of Kumaun, Uttaranchal were determined during April 1999 to March 2001. A total of 45 species belonging to 9 insect orders were collected. Herbivores were dominant in terms of number of species (61.8%), number of individuals (54.3%) and biomass (64.5%). Maximum population density and biomass were 7.0 m^{-2} and 376.7 mg m^{-2}, respectively. Mean Shanon-Wiener diversity index H' was 1.18. Mean secondary net production due to herbivores was 18.0 kJ m^{-2} yr^{-1}. Herbivores consumed a mean of 132.57 kJ m^{-2} yr^{-1} of the plant biomass.

KEYWORDS: Insect diversity, secondary net production, herbivory, cultivated land, Kumaun

INTRODUCTION

The structure of agricultural landscape due to intensive cultivation exerts a major impact on the standing crop and richness of the fauna of ecosystems (Ryszkowski, 1985). Composition, abundance and diversity of species in different crops have been the object of intensive studies (Bioteau, 1983; Karg *et al.*, 1985; Ryszkowski *et al.*, 1993; Armstrong, 1995; Clark, 1999; Grutzmacher and Link, 2000).

The objectives of the present study were to investigate whether intensive farming exerts any impact on the richness of the insect fauna and standing crop of cropland ecosystem in tarai region of Kumaun, Uttaranchal. Species richness, density and biomass, species diversity, secondary net production and insect herbivory have been investigated in a cropland ecosystem from April 1999 to March 2001.

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MATERIAL AND METHODS

The study site is a 5 ha area of cropland at Kicha (29° 55′ N and 79° 40′ E; 240 m altitude) about 10 km from G.B. Pant Agricultural University, Pantnagar, with an annual rainfall of 3370 mm. The maximum temperature ranged from 6.3°C (January) to 25.3° (July). The maximum relative humidity ranged from 67% (April) to 92.9% (November) and the minimum relative humidity ranged from 25.3% (April) to 72.9% (August). Maximum rainfall (73.4%) occurred in the rainy period during the months of July to September. On this basis, the year can be divided into three seasons namely, rainy (July to October), winter (November to February) and summer (March to June).

Two crops are grown in a year: July to mid October (Paddy) and from November to April (Wheat). May–June is the fallow period. The cropland fields are under manual tillage in the shallow layers of the soil (5 cm).

The population density was estimated by the removal trapping method. For this purpose, a cage with each side of 1 m^2 area was constructed, with an entrance of 80 × 40 cm on one side 10 cm above ground level. Wire gauze of 5 meshes per cm was fixed on all sides except on the side facing the ground. This mesh size of wire gauze prevented escape of insects from the cage. Sampling from 5 different areas at 15 days interval was done, except in winter when it was done monthly, ensuring that the cage did not disturb the tips of the vegetation. The trapped insects were killed in jars containing ethyl acetate.

Collected insects were oven-dried to constant weight (60°C for 24 h). Each specimen was weighed in a single pan electric balance (0.01 mg accuracy) for biomass estimation. The insects were separated into species and individuals occupying different trophic levels i.e., herbivores, omnivores, saprophages, parasites and predators.

Species diversity $H'(P)$ was calculated using Shanon–Wiener (Shanon and Wiener, 1963) expression.

$$H'(P) = \sum_{i=0}^{S} P_i \log P_i$$

where $P_i = \frac{n_i}{N}$; n_i is the number of species present in the season; and N is the number of individuals, S denotes the number of seasons.

Secondary production was calculated using Wiegert's (1965) expression:

$$P = S \sum_{i=2}^{n} \frac{(N_i + N_{i-1})}{2} (W_i - W_{i-1})$$

where, N_i is the number of herbivores present at time i, W_i is the mean weight per insect at time; n is the sampling period; S is the weight of standing crop at time $i = 1$. It was assumed that $N_i \leq N_{i-1}$ and $W_i \geq W_{i-1}$. When W_i was less than W_{i-1}, production was considered as zero.

Impact of herbivores on vegetation has been calculated using weight-specific consumption (Kaushal and Joshi, 1991) and the time series biomass data determined in the field. Total annual consumption has been obtained by totalling the consumption

of all seasons calculated as under:

$$C_s = B \times N \times C_w.$$

where, C_s is the seasonal consumption, B is the mean seasonal biomass and is calculated using Petrusewicz and Macfadyen (1970) expression:

$$B = \frac{1}{K} \sum_{i=1}^{i=k} B_i$$

where, B_i is the successive standing crop at time i, and k is the number of sampling times: N is the number of days in a season during which herbivores were available; and C_w is the weight-specific consumption.

RESULTS AN DISCUSSION

Species richness and trophic components

A total of 45 species were collected of which 17 were recorded in both years. Table 1 lists the total number of species and individuals of different orders collected.

Species richness was highest during summer and rainy (Table 2). Species richness was positively correlated with maximum temperature ($r = 0.74$; $P \leq 0.01, df = 24$), minimum temperature ($r = 0.797$; $P \leq 0.01$, $df = 24$) and rainfall ($r = 0.489$; $P \leq 0.01, df = 24$).

On the basis of number of species collected, 61.8% were herbivores, 29.2% predators, 3.0% each omnivores, saprophages and parasitoids, and on the basis of number of individuals, 54.3% were herbivores, 41.2% predators, 3.5% omnivores, 0.8% saprophages and 0.2% parasitoids and on the basis of biomass, 64.5% were herbivores, 32.0% predators, 3.0% omnivores, 0.4% saprophages and 0.1% parasitoids.

Bioteau (1983) and Ryszkowski *et al.* (1993) have also reported that herbivores were the dominant insect group in comparison to other trophic levels in agroecosystems because they are the food sources for parasitoids and predators.

Density and biomass

Strong inter-annual variation in population density occurred: density varied from 0 to 7.4 m^{-2} during 1999–2000, and from 0 to 3.4 m^{-2} during 2000–2001 (Fig. 1). Maximum number of insects were recorded during the wet period, and the minimum during winter season (Fig. 1).

Density of insects was positively correlated with the maximum temperature ($r = 0.615$; $P \leq 0.01$; $df = 24$), minimum temperature ($r = 0.71$; $P \leq 0.01, df = 24$), and rainfall ($r = 0.45$; $P \leq 0.01, df = 24$).

Nummelin (1996) and Kaushal and Joshi (1997) have also reported maximum density of insects during the rainy period. Unfavourable conditions i.e. extremely low and high temperature during dry conditions result in decrease in insect population density (Singh and Yadava, 1993; Nummelin, 1996).

The data presented in Fig. 2 reveal that variations also occur in biomass values.

TABLE 1. Species composition of different insect orders recorded in the cropland

Taxa	No. of individuals	
	April, 1999–March, 2000	April, 2000–March, 2001
Lepidoptera		
Danaidae		
Danaida chrysippus chrysippus L.	2	3
Nymphalidae		
Precis almana L.	1	–
Euthalia garuda garuda L.	1	–
Papilionidae		
Papilio demoleus L.	3	4
P romalus L.	–	1
Pieridae		
Pieris spp.	3	–
Pieris canidia Sparr.	11	5
Terias hecabe L.	12	6
Pyralidae		
unidentified	2	2
Saturnidae		
Melanitis ledaismene Cr.	14	8
Orthoptera		
Acrididae		
Acrida exaltata Walk.	17	9
A. turrita L.	10	4
Attractomorpha spp.	15	9
Ceracria deflorata Brun.	8	1
Hieroglyphys purcifer	6	–
Hetracris robusta Serv.	–	3
Poecilocerus pictus Fabr.	1	–
Schistocerca spp.	–	4
unidentified (nymphs)	–	2
Tettigonidae		
Elimaea spp.	–	1
Coleoptera		
Cantheridae		
Mylabris phalerata Pall.	1	–
Chrysomelidae		
Aulacophora foveicollis Lucas	–	1
Monolepta signata Oliver	1	2
Cicindelidae		
Cicindela flavomaculata Hope	3	–
Coccinelidae		
Coccinella transversalis F.	–	3
Coccinella septumpunctata F.	3	5
Henosepilachna vigintioctopunctata F.	–	2

TABLE 1. Contd...

Taxa	No. of individuals	
	April, 1999–March, 2000	April, 2000–March, 2001
Micraspis vincta Gorh.	1	–
Monochilus sexmaculata F.	–	3
Curculionidae		
Tanymecus circumdatus Wideman	–	1
Scarabaeidae		
Anomala polita	–	1
Chiloloba acuta Wideman	2	–
Odonata		
Libellulidae		
Brachythemis contaminata Fabr.	52	3
Crocothem s. servila Drury	14	4
Orthetrum s. sabina Drury	19	5
Pantala flavescons Fabr.	17	3
Rhyothemis variegata Joh.	–	5
Hemiptera		
Fulgoridae		
Dictyoptera pallida Don.	1	–
Cercopidae		
Phymatostetha dorsivitta Walk.	3	–
Pyrilla spp.	5	–
Pentatomidae		
Eurydema pulchurum Westw.	1	–
Hymenoptera		
Formicidae		
unidentified	–	8
Scoliidae		
Campsomeriella collaris collaris Fabr.	1	–
Vespidae		
Polistes spp.	9	3
Apidae		
unidentified	2	2
Diptera		
Asilidae		
Omatius spp.	–	1
Muscidae		
Musca domesticus	–	1
Mantodea		
Mantidae		
Hierodula coarctata	–	1
Neuroptera		
Ascalaphinae		
Heliocomitus dicax	–	1

TABLE 2. Monthly variation in the species content of different taxa in the cropland during April 1999–March 2001.

Taxa	April	May	June	July	August	September	October	November	December	January	February	March
Lepidoptera	7 (35.0)	3 (18.8)	1 (8.3)	2 (11.1)	3 (13.0)	4 (25.0)	4 (44.5)	4 (80.0)	–	–	–	2 (40.0)
Orthoptera	2 (10.0)	7 (43.7)	2 (16.7)	6 (33.3)	7 (30.6)	5 (31.2)	2 (22.2)	–	–	–	1 (50.0)	1 (20.0)
Coleoptera	4 (20.0)	–	1 (8.3)	4 (22.2)	4 (17.4)	2 (12.5)	–	–	–	–	–	–
Odonata	4 (20.0)	4 (25.0)	5 (41.7)	3 (16.7)	5 (21.7)	3 (18.8)	2 (22.2)					1 (20.0)
Hemiptera	1 (5.0)	–	–	2 (11.1)	1 (4.3)	–	–	–	–	–	–	–
Hemenoptera	2 (10.0)	2 (12.5)	1 (8.3)	1 (5.6)	2 (8.7)	2 (12.5)	–	1 (20.0)	–	–	1 (50.0)	1 (20.0)
Diptera	–	–	2 (16.7)	–	–	–	–	–	–	–	–	–
Mantodea	–	–	–	–	–	–	1 (11.1)	–	–	–	–	–
Neuroptera	–	–	–	–	1 (4.3)	–	–	–	–	–	–	–
Total	20 (100.0)	16 (100.0)	12 (100.0)	18 (100.0)	23 (100.0)	16 (100.0)	9 (100.0)	5 (100.0)	–	–	2 (100.0)	5 (100.0)

Figures in parentheses are percent values of total species during the month.

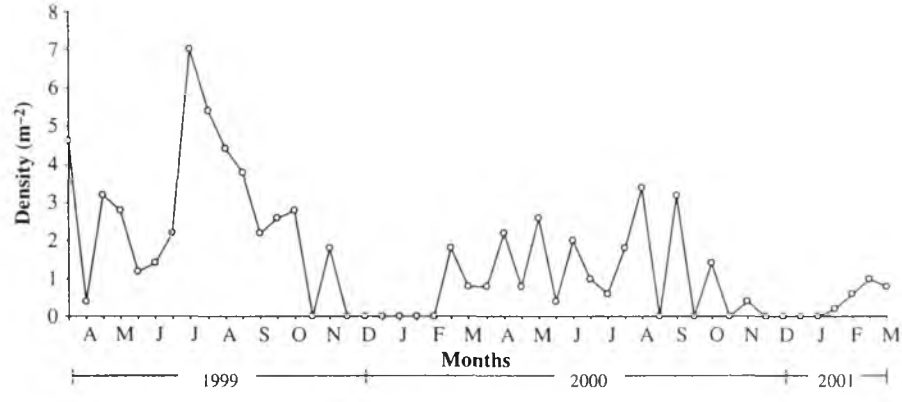

FIGURE 1. Variation in the density of insects during 1999–2001.

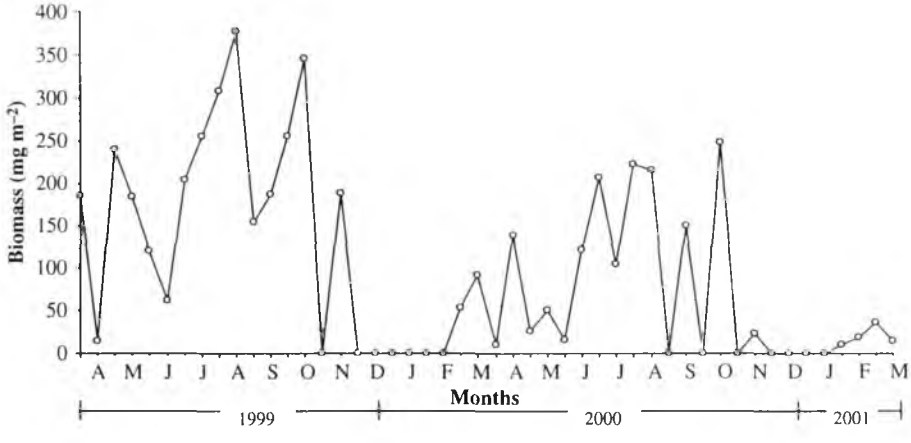

FIGURE 2. Variation of biomass of insects during 1999–2001.

Biomass of insects ranged from 0 to 376.7 mg m^{-2} during 1999–2000, and from 0 to 248.7 mg m^{-2} during 2002–2001. Total insect biomass was 1.84 times higher in 1999–2000 than during 2000–2001.

Biomass was positively correlated with density ($r = 0.875$; $P \leq 0.01, df = 24$).

Species diversity

The Shanon–Wiener index H' varied from 0 to 1.44 with a mean of 1.18 recorded in the present study indicated low diversity of insects (Table 3). Species diversity was more during wet period but was low during winter season when the temperature was low in the present study. Low species diversity (1.18) observed in the present study could be due to mono cropping pattern, predatory insects or human disturbances.

TABLE 3. Shanon-Wiener diversity index (H') of insect fauna.

Month	April 1999–March 2000	April 2000–March 2001	April 1999–March 2001
April	1.43	1.35	1.41
May	1.41	1.42	1.44
June	1.43	1.31	1.42
July	1.43	1.41	1.44
August	1.41	1.44	1.43
September	1.43	1.43	1.44
October	1.41	1.42	1.41
November	1.44	1.0	1.43
December	–	–	–
January	–	–	–
February	–	1.41	1.41
March	1.32	1.44	1.39
Mean	1.05	1.12	1.18

Human disturbances (Evans, 1984), predatory insects (Bioteau, 1983) and cutting of vegetation (Morris and Lakhani, 1979) have been reported to cause low species diversity in different land use systems.

Secondary net production

The tissue production estimates of herbivores in the present study is based on the calculations of the mean biomass of herbivores on each sampling date during 1999–2001. Cumulative net secondary production was 1295.7 mg m^{-2} yr^{-1} in 1999–2000 (25.91 kJ m^{-2} yr^{-1}) when converted to joules by multiplying with 22 J mg^{-1} (Kaushal and Joshi, 1991) and 340.6 mg m^{-2} yr^{-1} in 2000–2001 (7.49 kJ m^{-2} yr^{-1}) (Fig. 3). Mean secondary production was 818.2 mg m^{-2} yr^{-1} (18.0 kJ m^{-2} yr^{-1}).

Secondary net production values recorded in the present study fall in the range of 2.67 to 3407 kJ m^{-2} for herbivores in different habitats (Köhler *et al.*, 1987; Blummer and Diemer, 1996; Kaushal and Joshi, 1997). Low secondary production of herbivores (18.0 kJ m^{-2} yr^{-1}) in the present study could be attributed to low population density of insects.

Insect herbivory

The effect of herbivores on plant production is usually estimated from the amount of plant biomass that is consumed by herbivores and is expressed in weight or energy units.

On the basis of weight-specific consumption (Kaushal and Joshi, 1991), total consumption by herbivores in the cropland was 155.9 kJ m^{-2} yr^{-1} during 1999–2000, and 109.23 kJ m^{-2} yr^{-2} during 2000–2001. Average consumption by herbivores during 1999–2001 was 132.57 kJ m^{-2} yr^{-1} (Table 4).

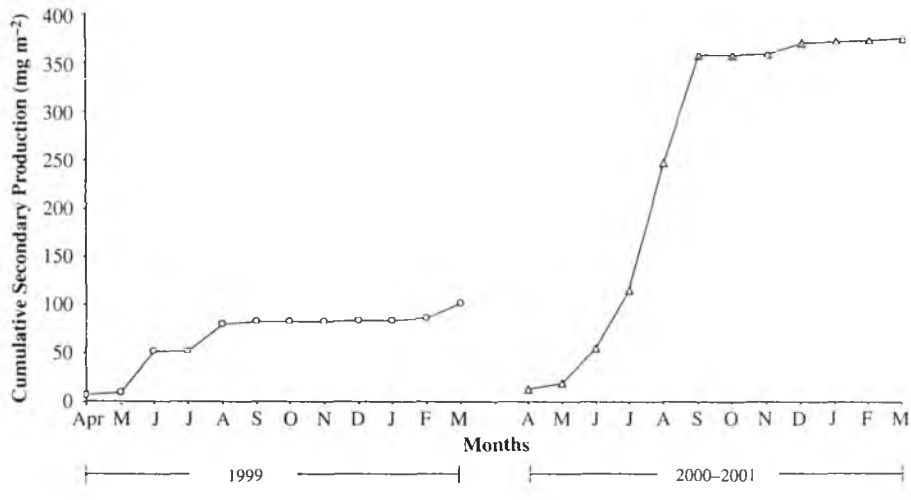

FIGURE 3. Cumulative net secondary production of herbivores during 1999–2001.

TABLE 4. Seasonal and annual consumption (kJ m^{-2} yr^{-1}) by herbivores in the cropland during April, 1999 to March, 2001.

Season	No. of days	Mean biomass* (mg $insect^{-1}$)	Consumption (kJ m^2)
April, 1999–March, 2000			
Summer (March–June)	122	53.8 × 22.4 × 0.302**	44.40
Rainy (July–October)	123	106.4 × 22.4 × 0.302	88.53
Winter (November–February)	120	28.3 × 22.4 × 0.302	22.97
Total consumption (KJ m^{-2} yr^{-1})			155.90
April, 2000-March, 2001			
Summer (March–June)	122	28.0 × 22.4 × 0.302	23.11
Rainy (July–October)	123	91.7 × 22.4 × 0.302	76.30
Winter (November–February)	120	12.1 × 22.4 × 0.302	9.82
Total consumption (KJ m^{-2} yr^{-1})			109.23
Average Consumption during 1999–2001 (kJ m^{-2} yr^{-1})		132.57	

*Mean biomass calculated from field data.
**Weight-specific consumption after Kaushal and Joshi (1991).

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REFERENCES

Armstrong, G. (1995) Carabid beetle (Coleoptera: Carabidae) diversity and abundance in organic potatoes and conventionally grown potatoes in the north of Scotland. *Pedobiologia* **39**: 231–237.

Blummer, P. and Diemer, M. (1996) The occurrence and consequences of grasshopper herbivory in an alpine grassland, Swiss central Alps. *Arctic and Alpine Research* **28**: 435–440.

Bioteau, G. (1983) The Arthropod communiy of potato fields in New Brunswick. *Canadian Entomologist* **115**: 847–853.

Clark, M. S. (1999) Ground beetle abundance and community in conventional and organic tomato systems of California's Central Valley. *Applied Soil Ecology* **11**: 199–206.

Evans, E. W. (1984) Fire as natural disturbance to grasshopper assemblage of tall grass prairie. *Oikos* **43**: 9–16.

Grutzmacher, A. D. and Link, D. (2000) Survey of the entomofauna associated with potato varieties during two crop seasons. *Pesquisa-Agropecuaria-Brasileria* **35**: 653–659.

Karg, J., Margarit, G., Hondru, N. and Gogoasa, C. (1985) Preliminary data regarding the influence of landscape types on the epigeic insects from wheat an alfalfa crops. *Problem Protection Plantetor (Bucharest)* **3**: 289–302.

Kaushal, B. R. and Joshi, P. C. (1991) Energy dynamics of grasshopper population in a temperate grassland community. *Australian Journal of Ecology* **16(3)**: 295–300.

Kaushal, B. R. and Joshi, P. C. (1997) Density, Biomass and Nutrient concentration of above ground insects in a temperate grassland community. *Entomon* **22(1)**: 41–49.

Köhler, G., Brodhun, H. P. and Schaller, G. (1987) Ecological energetics of Central European grasshoppers. *Oecologia (Berlin)* **74**: 112–121.

Morris, M. G. and Lakhani, K. H. (1979) Responses of grassland invertebrates to management by cutting I. Species diversity of Hemiptera. *J. Appl. Ecol.* **16**: 77–98.

Nummelin, M. (1996) The community structure of arthropods in virgin and managed sites in the Kibale Forest, Western Uganda. *Tropical Ecology* **37(2)**: 203–216.

Petrusewicz, K. and Macfadyen, A. (1970) Productivity of terrestrial animals. In: *Principles and Methods*, IBP Handbook, Blackwell Scientific: Oxford, p.13.

Ryszkowski, L. (1985) Improverishment of soil fauna due to agriculture. In: *Soil Ecology and Management*, Cooley, J. H. (Ed). 6–17.

Ryszkowski, L., Karg, J., Margarit, G., Paoletti, M. G. and Zlotin, R. (1993) Aboveground insect biomass in agriculture landscapes of Europe. In: *Ecology and Agroecosystems*, Bunce, R. G. H., Ryszkowski, L. and Paoletti, M. G. (Eds). Lewis Publishers: London, 71–82.

Shanon, C. E. and Wiener, W. (1963) *The Mathematical Theory of Communications*, University of Illinois Press: Champaigh.

Singh, T. B. and Yadava, P. S. (1993) Population dynamics, biomass and secondary productivity of aboveground insects in a sub-tropical forest ecosystems in Shiroy hills, Manipur. *Tropical Ecology* **34(1)**: 113–119.

Wiegert, R. G. (1965) Energy dynamics of the grasshopper population in an old-field and alfalfa ecosystems. *Oikos* **16**: 161–176.

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Aphelinid parasitoids of *Bemisia tabaci* (Gennadius) (Homoptera: Aleyrodidae) in India

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ABSTRACT: The aphelinid parasitoids of whiteflies, particularly *Bemisia tabaci* in India, were explored. Surveys were made from 1998 to 2003 in the states of Kerala. Tamil Nadu, Karnataka, Maharashtra, Orissa, Bihar, Jharkhand and West Bengal. Ten aphelinid parasitoids were identified. *Encarsia sophia* (Girault and Dodd) [=*Encarsia transvena* (Timberlake)], *E. bimaculata* (Heraty and Polaszek), *E. nigricephala* (Dozier), *E. strenua* (Silvestri), *E. haitiensis* (Dozier) [=*E. meritoria* (Gahan)], *E. guadeloupae* (Viggiani), *E. azimi* (Hayat), *E. pergandiella* (Howard), *Eretmocerus mundus* (Mercet) and *Eretmocerus* sp. *E. transvena* was found to be widely prevalent, attacking *B. tabaci* in all the regions surveyed irrespective of host crops. *Er. mundus* was prevalent in Nagpur, Parbhani, Coimbatore, Chennai, Bangalore, Hassaragatta, Kolar, Ranchi, Patna, Dholi Kolkata and Bhubaneswar in *B. tabaci* on cotton, water melon, brinjal, sunflower, bitter gourd and cucurbits; and failed to multiply on cassava-reared *B. tabaci* population from Trivandrum. *E. nigricephala*, *E. pergandiella* and *E. strenua* are first reports from India.

KEYWORDS: Parasitoid survey, aphelinid, *Encarsia*, *Eretmocerus*, *Bemisia tabaci*

INTRODUCTION

Bemisia tabaci (Gennadius) (Homoptera: Aleyrodidae) has been reported on more than 600 crop and weed hosts. It is a vector of 70 plant-infecting viruses in tropical and sub-tropical countries (Brown *et al.*, 1995; Perring, 2001). One of the key management challenges posed by the *B. tabaci* is its ability to develop resistance against insecticies (Cock, 1993; Castle, 1998). Long-term management of the whitefly demands an

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integrated approach in which natural enemies forms one of the key components. Research overseas indicated that parasitoids offer a high potential in managing the pest (Kirk *et al.*, 2000; Gerling *et al.*, 2001). Parasitic wasps of three genera, *Amitus*, *Encarsia* and *Eretmocerus*, are among the most important natural enemies of the *B. tabaci* complex (Cock, 1986; Hoelmer, 1995). *Encarsia* Foerster, 1878, is a large genus of the chalcidoid family Aphelinidae, with currently about 280 described species (Polaszek *et al.*, 1992). About 110 *Encarsia* species are known to parasitize whiteflies (Babcock and Heraty, 2000). Despite considerable efforts, there are many geographical regions where the *Encarsia* fauna is still very poorly known. Therefore an attempt was made to assess the abundance of different aphelinid species attacking whiteflies, particularly *B. tabaci* in India.

MATERIALS AND METHODS

Survey

Survey of parasitoids of *Bemisia tabaci* was conducted in Nagpur and Parbhani (Maharashtra), Coimbatore, and Chennai (Tamil Nadu), Kanhangad, Kannur and Trivandrum (Kerala), Bhubaneswar (Orissa), Kolkata (West Bengal), Ranchi (Jharkhand), Patna and Dholi (Bihar) and Bangalore, Hassargatta and Kolar (Karnataka), in India, during 1998–2003.

Cassava, sweetpotato, cotton, pigeon pea, sunflower, brinjal, cowpea, cucurbits, bitter gourd, tobacco, banana, *Cassia* sp., and several ornamental crops/crotons were covered in this survey. The plant parts infested with the whitefly at roadside, parks kitchen gardens, orchards, and crop fields in several institutes, university campuses, factory premises and farmer's fields were collected. Most of the specimens were reared on *B. tabaci*, *Dialeurodes* sp. *Trialeurodes* sp. or *Aleurodicus dispersus* (Russel). Each sample was given a unique code number and the host plant, host whitefly species, date, location and collector were noted. Nymphs of parasitized hosts were kept in emergence chambers and the emerging parasitoids were preserved into 70% ethanol. Percentage of parasitism of different parasitoids in the field was recorded. Temperature and relative humidity in the field were measured. Based on characteristic features for taxonomic identification, the species of *Encarsia* and *Eretmocerus* were ascertained (Polaszek *et al.*, 1992; Schauff *et al.*, 1996; Zolnerowich and Rose, 1998; Babcock and Heraty, 2000; Heraty and Polaszek, 2000; Schmidt *et al.*, 2001), and again they were reconfirmed with taxonomic experts.

To collect samples, whitefly infested leaves were examined with a pocket microscope (x60) for the presence of parasitised pupae. The parasitised pupae collected from the field were separated on the basis of its pupal colour; black in *Encarsia* and yellowish in *Eretmocerus*. They were kept separately in glass tubes with 10% honey as food, until the emergence of parasitoids. In addition *B. tabaci* infested leaves of all crops were collected. All the leaf samples were held in the laboratory, in petridishes, until adult parasitoids emerged. Dead parasitoids were collected and preserved in 70% alcohol. In the laboratory, the parasitoid specimens prepared using the method

for slide mounting described by Noyes (1982) modified by Heraty and Polaszek (2000). Emerged live adult parasitoids were released on *B. tabaci* in cages on cotton, sweet potato, tobacco, tomato, bhendi, brinjal and cassava plants. Separate collections were maintained in a screen house. Emerged adults were released on their respective host/plants in cages. The angle iron frame cages were 70 cm (height) × 42 cm square and covered with organdy cloth on three sides. A transparent plastic sheet covered the remaining side and the cage top. Cassava and sweetpotato associated population of *B. tabaci* (Lisha *et al.*, 2003) were used as host for multiplying different parasitoids in cages (Temperature 25–30°C, RH 70–75%).

Slide preparation of specimens and their examination

All specimens used in this study were mounted on slides as described by Noyes (1982) with the following modifications: specimens were placed in 10% KOH for 5–8 min (depending on whether the specimen was dry or preserved in ethanol) and incubated at 97°C using a block heater. The terminology followed was as suggested by Heraty and Polaszek (2000).

Voucher specimens

Voucher specimens of various *Encarsia* and *Eretmocerus* spp. were deposited in the Division of Crop Protection, Central Tuber Crops Research Institute, Trivandrum, India.

RESULTS AND DISCUSSION

Collection of aphelinid parasitoids of *B. tabaci* revealed presence of ten aphelinid parasitoids; viz., *Encarsia transvena* (Timberlake) (= *E. sophia* Girault and Dodd), *E. bimaculata* (Heraty and Polaszek), *E. nigricephala* (Dozier), *E. strenua* (Silvestri), *E. meritoria* (Gahan), *E. azimi* (Hayat), *E. guadeloupae* (Viggiani), *E. pergandiella* (Howard), *Eretmocerus mundus* (Mercet) and *Eretmocerus* sp. (Table 1). Collection sites, crop/plants and host whitefly and percentage of parasitism are given in Tables 1 and 2.

Accurate scientific names and synonymies of parasitoids were determined following Polaszek *et al.* (1992, 1999), Schauff *et al.* (1996), Zolnerowich and Rose (1998), Babcock and Heraty (2000) and Heraty and Polaszek (2000). *E. transvena* and *E. strenua* were differentiated after by Schauff *et al.* (1996); and *E. bimaculata*, after Heraty and Polaszek (2000). *E. transvena, E. strenua* and *E. bimuaculata* come under 'strenua' group (Heraty and Polaszek, 2000). *E. pergandiella* and *E. nigricephala* were identified based on previous publication of Polaszek *et al.* (1992, 1999) and Schauff *et al.* (1996), and confirmed by taxonomic experts. Both parasitoids successfully multiplied on *B. tabaci* reared on tomato and cotton. *E. guadeloupae* and *E. azimi* were reared from *Aleurodicus dispersus* (Russel) and *Dialeurodes* sp., respectively. We tried to multiply *E. guadeloupae* and *E. azimi* on *B. tabaci*, but failed. *E. meritoria* was reared primarily on *A. dispersus* and secondarily on *B. tabaci*. *Er. mundus* was

TABLE 1. List of aphelinid parasitoids encountered during 1998–2003 in different parts of India

	Parasitoids	Crop/Plant	Location	Host
1.	*Encarsia transvena* Timberlake) [= *Encarsia sophia* (Girault & Dodd)]	Cassava, cotton sweetpotato, brinjal, cowpea, cucurbits, tobacco, tomato, bhendi, sunflower, water melon and bitter gourd	Trivandrum Kanhangad, Parbhani, Nagpur, Bhubaneswar, Ranchi, Patna and Dholi, Coimbatore, Chennai, Bangalore, Hassaragatta, Kolar and Kolkatta	*Bemisia tabaci*
2.	*E. strenua* (Silvestri)	Gardon rose and *Cassia* sp.	Trivandrum	*Trialeurodes* sp. *B. tabaci*
3.	*E. meritoria* (Gahan) [= *Encarsia haitiensis* (Dozier)]	Cassava, banana, guava and pomegranates	Kalliyoor (Trivandrum)	*B. tabaci Aleurodicus dispersus*
4.	*E. bimaculata* (Heraty & Polaszek)	Cotton	Coimbatore and Bangalore	*B. tabaci*
5.	*E. nigricephala* (Dozier)	Tomato	Trivandrum	*B. tabaci*
6.	*E. azimi* (Hayat)	Tomato	Bangalore, Hassaragatta	*Dialeurodes* sp.
7.	*E. gaudeloupae* (Viggiani)	Tomato, *Cassia* sp., banana, guava, poinsettia,	Bangalore, Hassaragatta	*A. dispersus*
8.	*E. pergandiella* (Howard)	Banana	Trivandrum	*B. tabaci* *Trialeurodes* sp.
9.	*Eretmocerus mundus* (Mercet)	Cotton, brinjal and tomato, sweet potato, water melon, bhendi, sunflower, cucurbits	Nagpur, Parbhai, Coimbatore, Chennai Bangalore, Hassaragatta, Kolar, Ranchi, Patna, Dholi, Kolkata and Bhubaneswar	*B. tabaci*
10.	*Eretmocerus* sp.	Brinjal and sunflower	Bangalore	*B. tabaci*

TABLE 2. Population of *Bemisia tabaci* and its parasitoids, and temperature and RH

Location	Month Date & Year	Host plant	Total whitefly population/ 10 plants*	Total parasitoid population**	Dy time temper ature in °C	Relative humidity (%)
Hassaragatta	01/03/2002	Cucumber	3804(1745)	259 (6.82%)	32.0	22
Bangalore	02/03/2002	Tomato	162 (61)	15 (9.2%)	32.0	22
"	"	Brinjal	939 (487)	59 (6.3%)	31.0	22
Hassaragatta	01//03/2002	Water melon	3750 (2699)	260 (6.9%)	31.0	21
"	"	Tomato	1128 (586)	70 (6.2%)	32.0	22
Kolar	03/03/2002	Tomato	462 (273)	60 (21.9%)	29.0	22
Nagpur	14/10/1999	Cotton	200 (110)	20 (10%)	32.6	58
"	"	Brinjal	211 (88)	27 (12.7%)	32.0	55
Parbhani	13/10/1999	Cotton	325 (211)	34 (10.5%)	28.0	60
"	"	Sun flower	157 (71)	29 (18.47%)	32.0	60
Coimbatore	19/10/2000	Pigeon pea	171 (40)	20 (11.6%)	32.0	40
"	"	Cotton	111 (3)	28 (25.2%)	32.0	40
"	20/10/2000	Brinjal	211 (15)	26 (12.3%)	30.0	40
"	"	Sun flower	14 (02)	Nil	30.0	40
Salem	12/08/1999	Cassava	275 (32)	17 (6.2%)	32.0	60
Trivandrum	01/10/1999	Cassava	256 (44)	31 (12.1%)	28.0	70
Kannur	26/02/2001	Bhendi	05 (02)	Nil	30.0	75
Kanhangad	27/02/2001	Cassava	80 (02)	02 (2.5%)	28.0	75
Kanhangad	"	Tobacco	142 (25)	13 (9.2%)	28.0	80
Chennai	28/06/2001	Cucurbits	–	16.11	–	–
Bhubaneswar	30/06/2001	Sweet potato	–	11.04	32.0	55
Dholi	03/07/2001	Sweet potato	–	17.11	–	–
Kolkata	01/07/2001	Sweet potato	–	11.02	–	–
Patna	02/07/2001	Bhendi	–	14.11	–	–
Ranchi	04/07/2001	Sweet potato	–	15.10	–	–

*Figures in parentheses represent total adult whitefly population
**Figures in parentheses represent percentage of parasitism
- Data not available.

identified as reported by Zolnerowich and Rose (1998). Morphological characters of *Eretmocerus* sp. in present study indicated that it showed some features of *Eretmocerus melanoscutus* (Zolnerowich and Rose) (Rose and Zolnerowich, 1997). However, this needs further studies to ascertain the identification.

Among the parasitoids collected, *E. transvena* was found to be the most dominant, attacking *B. tabaci* in all the regions surveyed, irrespective of the crops (Tables 1 and 2). *Er. mundus* was more abundant in Coimbatore than in other regions surveyed, but percentage of parasitism was higher in Kolar region (Table 2). In Ko-

lar, whitefly population was less compared to Hassaragatta and Bangalore, but *Er. mundus* populations was higher (21.9% parasitisation) (Table 2). In Hassaragatta, most of the watermelons were heavily infested with whiteflies and fairly good population of *Er. mundus*, *E. guadeloupae* and *E. azimi* were collected from Hassaragatta. *E. transvena* and *Er. mundus* were the most abundant parasitoids attacking *B. tabaci* on cotton in Parbhani and Nagpur (Maharashtra) accounting for 10% and 12.5% of parasitism (Table 2). *E. transvena* was the most dominant parasitoid of *B. tabaci* in Kerala. It was present throughout the region surveyed. *Er. mundus* collections were obtained from Coimbatore, Chennai, Bangalore, Hassaragatta, Kolar, Parbhani, Nagpur, Ranchi, Patna, Bhubaneswar, Kolkatta and Dholi. But interestingly, no collections from Kerala had *Er. mundus*. Natarajan (1990) reported that *E. transvena* (= *E. flava*) and *Er. mundus* were important parasitoids of *B. tabaci* on cotton during 1985–88 in Tamil Nadu, India. Lal (1980) and Palaniswami *et al.* (2001) reported that the population of *E. transvena* and its host *B. tabaci* occurred throughout the year in cassava ecosystem. Kapadia and Puri (1989, 1990) reported that among the six aphelinid parasitoids recorded on *B. tabaci*, *E. transvena* was the most important, causing 25–63% parasitisation under the Maharashtra condition. *Er. mundus* was also reported from Maharashtra (Kapadia and Puri, 1993), and highest percentage of parasitism was reported on cotton and soybean. Now both *E. transvena* and *E. flava* (*E. shafeei*) are considered as synonymous (Polaszek *et al.*, 1992). Mani *et al.* (2001) reported *E. guadeloupae* and *E. azimi* from Bangalore. Beevi *et al.* (1999) reported *E. meritoria* from Trivandrum. Heraty and Polaszek (2000) reported *E. bimaculata* from India. Hayat (1998) reported the list of aphelinid parasitoids from India. *E. nigricephala, E. pergandiella, E. meritoria* were collected from Trivandrum from different crops like cassia, cassava, guava, pomegranate and banana plants (Table 1). *E. nigricephala, E. strenua* and *E. pergandiella* are first reports from India.

The present survey showed *Er. mundus* was dominant in Bangalore area followed by Coimbatore, Nagpur and Parbhani, and negligible in Kasargod, Kannur and Thiruvananthapuram. *Er. mundus* collection was mainly from cucumber, brinjal, cotton, sunflower, watermelon and bhendi. We never observed *Er. mundus* population on cassava in Bangalore, Bhubaneswar, Coimbatore, Thiruvananthapuram, Kannur, and Kassaragod. In Kerala, cassava is commonly infested by a cassava adapted population (cassava biotype) of *B. tabaci* (Lisha *et al.*, 2003). *Er. mundus* failed to develop on cassava biotype of *B. tabaci* in our net house condition whereas it multiplied fast on sweet potato biotype. *Er. mundus* is the most potential and widely used parasitoid of *Bemisia tabaci* in US and Europe, especially in poly house condition (Heinz and Parrella, 1998). Hence these observations are useful for designing mass rearing of this parasitoid on *B. tabaci* for biological control programme.

The data indicate that a large number of parasitoid species attack *B. tabaci* in India. *E. transvena* was the most abundant species followed by *Er. mundus*. The large, naturally occurring complex of parasitoids attacking *B. tabaci* in India causes high level of mortality in the absence of conventional insecticides. A fairly good percentage of parasitism was reported from all the regions surveyed. Therefore,

conserving the large complement of natural enemies through the judicious use of selective insecticides and augmentation of these parasitoids should form an important ecofriendly component of integrated pest management of *B. tabaci*.

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REFERENCES

Babcock, C. S. and Heraty, J. M. (2000) Molecular markers distinguishing *Encarsia formosa* and *Encarsia luteola* (Hymenoptera: Aphelinidae). *Annals of Entomological Society of America* **93(4)**: 738–744.

Beevi, S. P., Lyla, K. R. and Vidya, P. (1999) Report of *Encarsia* (Hymenoptera: Aphelinidae) on spiralling whitefly, *Aleurodicus dispersus* Russell (Homoptera: Aleyrodidae). *Insect Environment* **5(1)**: 44.

Brown, J. K., Frohlich, D. R. and Rosell, R. C. (1995) The sweetpotato or silverleaf whiteflies. Biotypes of *Bemisia tabaci* or a species complex. *Annual Review of Entomology* **40**: 511–534.

Castle, S. J. (1998) Primary pest or synthetically induced? The role of insecticides and other factors in the pest status of *Bemisia tabaci*. Silverleaf Whitefly. National Research, Action and Technology Transfer Plan, 1997–2001; First Annual Review of the Second Five Year Plan. *Proc. of the Ag. Res. Serv.*, United States Department of Agriculture: Washington, DC, USA.

Cock, M. J. W. (1986) *Bemisia tabaci*-a literature survey on the cotton whitefly with an annotated bibliography. In: *CABI*, International Institute of Biological Control: Ascot, London, p. 121.

Cock, M. J. W. (1993) *Bemisia tabaci an update 1986–1992*, CAB International Institute of Biological Control: Ascot, UK, p. 78.

Gerling, D., Alomar, S. and Arno, J. (2001) Biological control of *Bemisia tabaci* using predators and parasitoids. *Crop Protection* **29(2)**: 779–799.

Hayat, M. (1998) Aphelinidae of India (Hymenoptera: Chalcidoidea), a taxonomic revision. *Memoirs on Entomology, International* **13**: p. 416.

Heinz, K. and Parrella, M. P. (1998) Host location and utilisation by selected parasitoids of *Bemisia argentifolii* (Homoptera: Aleyrodidae): Implications for augmentative biological control. *Environmental Entomology* **27(3)**: 773–778.

Heraty, J. M. and Polaszek, A. (2000) Morphometric analysis and descriptions of selected species in the *Encarsia strenua* group (Hymenoptera: Aphelinidae). *Journal of Hymenopteran Research* **9(1)**: 142–169.

Hoelmer, K. (1995) Whitefly parasitoids: Can they control field population in *Bemisia*. In: *Bemisia: Taxonomy, Biology, Damage and Management*, Gerling, D. and Mayer, R. T. (Eds). Intercept, Andover UK, 451–476.

Kapadia, M. N. and Puri, S. N. (1989) Seasonal incidence of natural enemies of *Bemisia tabaci* (Gennadius). *Indian Journal of Ecology* **16**: 164–168.

Kapadia, M. N. and Puri, S. N. (1993) Parasitism of whitefly on different host plants under greenhouse conditions. *Journal of Maharashtra Agricultural University (India)* **18(2)**: 312–313.

Kapadia, M. N. and Puri, S. N. (1990) Development, relative proportions and emergence of *Encarsia transvena* (Timberlake) and *Eretmocerus mundus* Mercet, important parasitoids of *Bemisia tabaci* (Gennadius). *Entomon* **15**: 235–239.

Kirk, A. A., Lacey, L. A., Brown, J. K., Coimperlik, M. A., Goolsby, J. A., Vacek, D. C., Wendel, L. E. and Napompeth, B. (2000) Variation in the *Bemisia tabaci* s. l. species complex (Homoptera: Aleyrodidae) and its natural enemies leading to successful biological control of *Bemisia* biotype B in the USA. *Bulletin of Entomological Research* **90(4)**: 317–327.

Lal, S. S. (1980) A note on *Prospaltella flava* Shafee, an aphelinid parasitoid of *Bemisia tabaci* (Gennadius). *Madras Agricultural Journal* **67(8)**: 557–558.

Lisha, V. S., Antony, B., Palaniswami, M. S. and Henneberry, T. J. (2003) *Bemisia tabaci* (Gennadius) (Homoptera: Aleyrodidae) biotypes in India. *Journal of Economic Entomology* **96**: 322–327.

Mani, M., Krishnamoorthy, A. and Dinesh, M. S. (2001) Biological control studies on the spiralling whitefly *Aleurodicus dispersus* Russell (Homoptera: Aleyrodidae). *Entomon* **26**: 62–69.(spl. issue)

Natarajan, K. (1990) Natural enemies of *Bemisia tabaci* Gennadius and effect of insecticides on their activity. *Journal of Biological Control* **4(2)**: 86–88.

Noyes, J. S. (1982) Collecting and preserving chalcid wasps (Hymenoptera: Chalcidoidea). *Journal of Natural History* **16**: 315–334.

Palaniswami, M. S., Antony, B., Lisha Vijayan, S. and Henneberry, T. J. (2001) Sweetpotato whitefly *Bemisia tabaci*: Ecobiology, host interaction and natural enemies. *Entomon* **26**: 256–262.

Perring, T. M. (2001) The *Bemisia tabaci* complex. *Crop Protection* **20**: 725–737.

Polaszek, A., Abd-Rabou, S. and Huang, J. (1999) The Egyptian species of *Encarsia* (Hymenoptera: Aphelinidae): a preliminary review. *Zool. Mediterr. Leiden* **73**: 131–163.

Polaszek, A., Evans, G. A. and Bennet, F. D. (1992) *Encarsia* parasitoids of *Bemisia tabaci* (Hymenoptera: Aphelinidae: Homoptera: Aleyrodidae): a preliminary guide to identification. *Bulletin Entomological Research* **2**: 375–392.

Rose, M. and Zolnerowich, G. (1997) *Eretmocerus* Haldeman (Hymenoptera: Aphelinidae) in the United States, with descriptions of new species attacking *Bemisia* (*tabaci*) complex) (Homoptera: Aleyrodidae). *Proceedings of Entomological Society of Washington* **991(1)**: 1–27.

Schauff, M. E., Evans, G. A. and Heraty, J. M. (1996) A pictorial guide to the species of *Encarsia* (Hymenoptera: Aphelinidae) parasitic on whiteflies (Homoptera: Aleyrodidae) in North America. *Proceedings of the Entomological Society of Washington* **98(1)**: 1–35.

Schmidt, S., Naumann, I. D. and De Barro, P. J. (2001) *Encarsia* species (Hymenoptera: Aphelinidae) of Australia and Pacific Islands attacking *Bemisia tabaci* and *Trialeurodes vaporariorum* (Homoptera: Aleyrodidae) - a pictorial key and descriptions of four new species. *Bulletin of Entomological Research* **91(5)**: 369–387.

Zolnerowich, G. and Rose, M. (1998) Eretmocerus Haldeman (Hymenoptera: Aphelinidae) imported and released in the United States for control of *Bemisia* (*tabaci* complex) (Homoptera: Aleyrodidae). *Proceedings of Entomological Society Washington* **100**: 310–323.

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Aphid *Macrosiphum luteum* (Bukton) infests the orchid *Vanda coerulea*—A new report

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ABSTRACT: Aphid *Macrosiphum luteum* (Bukton) (Homoptera: Aphididae) infested orchid *Vanda coerulea* starting from September to December under open polyhouse conditions and its occurrence is reported first time in India.

KEYWORDS: Orchid, *Vanda coerulea*, *Macrosiphum luteum*

Vanda coerulea, commonly named as 'Autumn lady's tresses orchid' or 'Blue Vanda', a rare and beautiful flowering plant is popular due to its large, blue, tessellated flowers, opening from September to December. It is listed in CITES (Convention on International Trade of Endangered Species of Wild Flora & Fauna) Appendix II. As a parent this species have all the vital ingredients to produce a wide variety of floriculturally significant primary and secondary hybrids. So far, about 269 hybrids of *V. coerulea* have been registered with the Royal Horticultural Society. As the orchid species is commercially marketable, they are indiscriminately collected by both amateurs and professionals. Tribal people are often seen gathering huge quantities of these orchids from the wild during their flowering season and selling them in the local markets. In addition to the reckless collection and habitat destruction in wild, damage caused by pest and diseases pose direct threat.

Among more than 400 orchid species collected from different parts of the country, *Vanda coerulea* is maintained for its commercial utilization at National Research Center for Orchids, Pakyong, Sikkim. The plants are kept under open polyhouse/partial shade.

The aphid *Macrosiphum luteum* (Bukton) has been found to infest the flowers of *Vanda coerulea* from bud stage and remained till the flowers withered. The aphid suck the juice from buds as well as from opened flowers and simultaneously excrete honeydew which support the growth of black sooty mould, an unsightly fungus that mars the beauty of flower (Fig. 1). Honeydew secretion also invite black ants. Aphids are winged or wingless and form small colonies. Aphid infestation on *Vanda coerulea* has been seen starting from September to December under open polyhouse conditions.

FIGURE 1. *Macrosiphum luteum* (Bukton) infestation on *Vanda Coerulea*.

This aphid was first described from hothouse orchids in England (Pridgeon and Tillman, 1990). Also found in the Far East and the Pacific, it is established in Florida on the U.S. mainland (Blackman and Eastop, 2000; Pridgeon and Tillman, 1990). In Hawaii it infests orchids on Kauai, Oahu, Maui, and Hawaii (Nishida, 1992).

This aphid infests orchids of the genera *Oncidium, Cattleya, Lycaste, Brassia, Epidendrum, Laelia* and *Catasetum* (Swezey, 1945). Two of the more commonly reported species from cultivated orchids are the green peach aphid (*Myzus persicae*) and the cotton aphid or melon aphid (*Aphis gossypii*). The lily or arum aphid (*Aulacorthum circumflexum*) was reported from orchids in Connecticut (Anon, undated). The University of Hawaii Extension Service Crop Knowledge Master website (`http://www.extento.hawaii.edu`) lists the orchid aphid (*Sitobion luteum* as *Macrosiphum luteum*) and the fringed orchid aphid (*Cerataphis orchidearum*) as the main aphid pests on orchids in Hawaii. These latter two species are distributed widely in the tropics, and may be in temperate region greenhouse, having disseminated on plants. Worldwide, eight species of aphid from orchids: *Aulocorthum solani, A. dendrobii, A. circumflexum, Sitobion anselliae, S. indicum, S. luteum, Ceratapis orchidearum* and *Toxoptera aurantii* have been recorded (Raychaudhuri, 1983, Blackman and Eastop, 2000; Chakrabarti and Sarkar, 2001; Nagrare, 2004). However, the occurrence of *Macrosiphum luteum* (Bukton) on host orchid *Vanda coerulea* from India is the first report.

REFERENCES

Anon, (undated). Orchid (Orchidiceae)[sic]. Plant Pest Handbook, Connecticut Agricultural Experiment Station. `http://www.caes.state.ct.us` Plant Pest Handbook Files/pphO/pphorch.htm.

Blackman, R. L. and Eastop, V. F. (2000) *Aphids on the World's Crops: An Identification and Information Guide*, 2nd edition. John Wiley and Sons: New York.

Chakrabarti, S. and Sarkar, A. (2001) Supplement of the food plant catalogue of Indian Aphididae (Homoptera). *J. Aphidology* **15**: 9–62.

Nagrare, V. S. (2004) The black aphid, *Toxoptera aurantii* (B. De F.) infests the Orchid, Oncidium Gower Ramsay. *Entomon* **29**: 193–195.

Nishida, G. M. (1992) *Hawaiian Terrestrial Arthropod Checklist*, Bishop Museum Press: Honolulu, p. 135.

Pridgeon, A. M. and Tillman, L. L. (1990) *Handbook on Orchid Pests and Diseases*, American Orchid Society, Inc: West Palm Beach, Florida, p. 10.

Raychaudhuri, D. N. (1983) *Food Plant Catalogue of Indian Aphididae*, Aphidological Society of India: p. 188.

Swezey, O. H. (1945) Insects associated with orchids 2. *Macrosiphum luteum* (Buckton). *Proc. Haw. Ent. Soc.* **12**: 373.

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Two new aleyrodids (Hemiptera: Aleyrodidae) from India

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ABSTRACT: Two new species of aleyrodids viz., *Aleuroclava trivandricus* and *Singhiella bauhiniae* are described along with a key to the Indian species of the genus *Singhiella*.

KEYWORDS: Aleyrodidae, new species, *Aleuroclava trivandricus*, *Singhiella bauhiniae*

INTRODUCTION

The genus *Aleuroclava* was described by Singh (1931). Jesudasan and David (1990) made revisionary study of the genus. Sundararaj and David (1993) added 14 new species to the genus. Dubey and Sundararaj (2005) have documented 49 species of *Aleuroclava* from India with description of eight new species and keyed. Further, the genus *Singhiella* was described by Sampson (1943). So far, five species are on record in the genus *Singhiella* (Singh, 1931; David and Subramaniam, 1976; Qureshi and Qayyam, 1969; Jensen, 2001) from India. One new species each of these two genera is described and identification key to species of *Singhiella* is provided. The key for *Aleuroclava* by Dubey and Sundararaj (2005) is the latest one and not duplicated here. Registration numbers for types not yet received from depositories. Detailed descriptions of these species are given below.

Aleuroclava trivandricus Dubey and Sundararaj sp. nov. (Figs 1–3)

Puparium

White, with deposition of white wax on dorsum; oval, slightly constricted at the thoracic tracheal pore regions; 0.88–0.89 mm long and 0.68–0.69 mm wide, found singly and scattered on the under surface of leaves. Margin crenulate; anterior and

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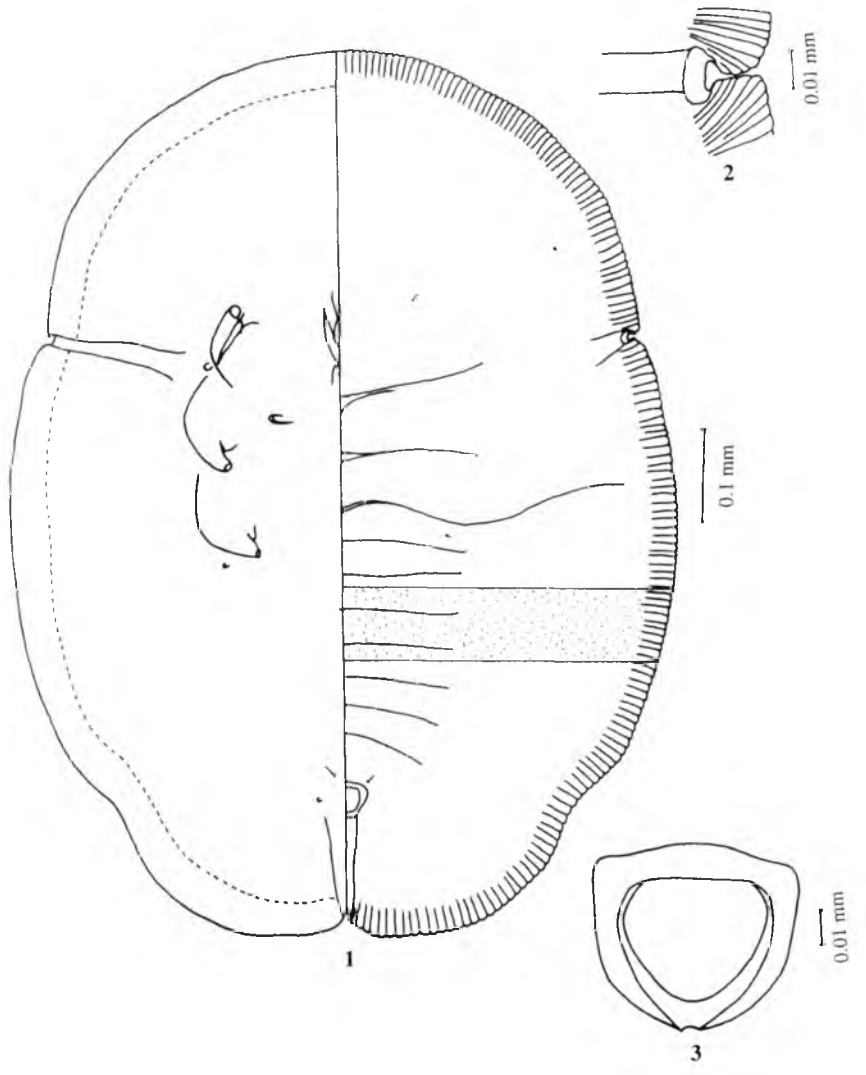

FIGURE 1. *Aleuroclava trivandricus* Dubey and Sundararaj sp. nov. 1. Puparium, 2. Thoracic tracheal pore, 3. Vasiform orifice.

posterior marginal setae respectively, 20 and 25 μm long; thoracic and caudal tracheal pores distinct with chitnised rim and without internal teeth.

Dorsum Dorsum finely granulated with sparsely distributed minute pores; submargin with sutures running mesad from margin distinct; submarginal and subdorsal setae, and median tubercles on abdominal segments absent.

Chaetotaxy Three pairs of minute setae-cephalic, first and eighth abdominal setae each 2.5 μm long. Caudal setae not discernable.

Vasiform orifice Subcircular, slightly notched at the hind end, wider than long, 45–47.5 μm long and 50–55 μm wide; operculum subcordate, 25 μm long and 35 μm wide. Lingula concealed; caudal furrow funnel-shaped, 77.5–88 μm long 7.5 μm wide and thoracic tracheal furrows distinct.

Venter Ventral abdominal setae cephalad of vasiform orifice 12.5 μm long and 35 μm apart. Caudal and thoracic tracheal folds distinct without dots or stipples. Antennae reaching base of prothoracic legs. Setae absent at the base of legs.

Holotype

One puparium, India: Kerala, Trivandrum, on *Terminalia* sp., 25.v.2001, Coll: A. K. Dubey. [Currently in second author's collection (IWST) subsequently to be transferred to NFICFRI].

Paratypes

Eight puparia, data as for holotype; India: Karnataka, Kumargiri; 4 puparia, on *Cinnamomum sulphuratum*, 10.ix.2001, Coll: A. K. Dubey. (ANIC, BMNH, IARI, IWST, NMNH, NTU, SMTD, USDA, ZMU).

Host plants

Terminalia sp. (Combretaceae), *Cinnamomum sulphuratum* (Lauraceae).

Distribution

India: Kerala: Trivandrum; Karnataka: Kumaragiri.

Etymology

Named after its collection locality, Trivandrum (Kerala).

Remarks

This species resembles *Aleuroclava turpiniae* (Meganathan and David) in having cephalothorax longer than abdomen and in the absence of submarginal/subdorsal setae, but differs in its distinct shape, in the presence of granulated dorsum, and minute eighth abdominal setae.

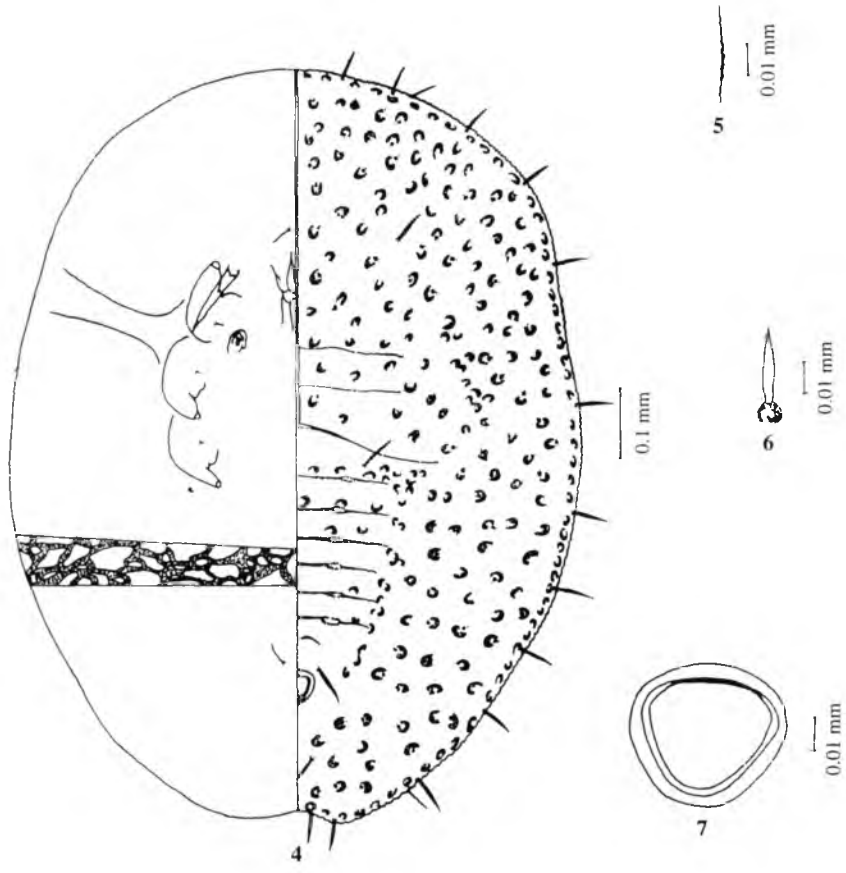

FIGURE 2. *Singhiella bauhiniae* Dubey and Sundararaj sp. nov. 4. Puparium, 5. Thoracic tracheal comb, 6. Submarginal seta, 7. Vasiform orifice.

Singhiella bauhiniae Dubey and Sundararaj sp. nov. (Figs. 4–7)

Puparium

White, with secretion of white wax; elliptical, broadest at the transverse moulting suture region and slightly constricted at the thoracic tracheal pores and depressed at caudal region; 0.80–1.08 mm long, 0.60–0.82 mm wide; found singly, 2–3 per leaf, on the under surface of leaves. Margin irregularly crenulate, 32–39 crenulations in 0.1 mm. Thoracic and caudal tracheal combs faintly indicated. Anterior and posterior marginal setae respectively, 42 and 46 μm long.

Dorsum Tuberculate. A row of minute submarginal tubercles present. Submedian pockets present on all the abdominal segment sutures. Submedian depressions present

on cephalic and pro-, meso- and metathorax. Longitudinal moulting suture reaching margin and transverse moulting suture reaching submedian area.

Chaetotaxy Four pairs of lanceolate setae-cephalic setae 16 μm long, first abdominal setae 18 μm long, eighth abdominal setae cephalolatered of vasiform orifice 18.5 μm long and caudal setae 38 μm long. Submargin with 12 pairs of lanceolate setae, 26–28 μm long. A pair of submarginal caudal setae, 13 μm long. Vasiform orifice subcordate, 38–48 μm long, 42–52 μm wide; operculum subcordate, 26–34 μm long, 32–42 μm wide. Lingula concealed. Thoracic and caudal tracheal furrows not indicated.

Venter With irregular impressions. A pair of ventral abdominal setae 18 μm long, 38–44 μm apart. A pair of setae at base of pro-, meso- and metathoracic legs, 5 μm long and a pair of minute setae at base of rostrum, 8 μm long. Antennae reaching base of prothoracic legs. Thoracic tracheal folds distinctly indicated while caudal tracheal fold faintly discernible.

Holotype

One puparium, India: Karnataka, Kudremukh National Park, on *Bauhinia phoenicea*, 7.viii.2001, Coll: A. K. Dubey. [Currently in second author's collection (IWST) subsequently to be transferred to NFICFRI].

Paratypes

10 puparia, data as for holotype. (ANIC, BMNH, IARI, IWST, NMNH, NTU, SMTD, USDA, ZMU).

Host plant

Bauhinia phoenicea (Caesalpiniaceae).

Distribution

India: Karnataka: Kudremukh National Park.

Etymology

Named after its host plant genus, *Bauhinia*.

Remarks

This species resembles *Singhiella premnae* Martin (1999) in the presence of 12 pairs of submarginal setae and tuberculate dorsum, but differs in having lanceolate submarginal setae, a pair of lanceolate setae posterio-lateral to vasiform orifice on caudal region, and concealed lingula.

Key to Indian species of *Singhiella* Sampson

1. Submargin/subdorsum without a row of setae 2
– Submargin/subdorsum with a row of setae 3
2. Pores on the dorsum many and small; thoracic tracheal folds indicated; eighth abdominal setae posteriolaterad of vasiform orifice ..... *S. bicolor* (Singh)
– Pores on the dorsum few and large; thoracic tracheal folds not indicated; eighth abdominal setae slightly cephalolaterad of vasiform orifice ..... *S. crenulata* Qureshi and Qayyam
3. Cephalic, I, VIII and caudal setae not lanceolate, submargin without a row of lanceolate setae, simple setae may be present 4
– Cephalic, I, VIII and caudal setae lanceolate, submargin with a row of 12 pairs of lanceolate setae ..... *S. bauhiniae* sp. nov.
4. Subdorsum with fourteen pairs of setae; caudal tracheal furrow without distinct granules; minute setae at base of meso- and metathoracic legs present 5
– Subdorsum with six pairs of setae; caudal tracheal furrow with distinct granules; setae at base of meso- and metathoracic legs absent ..... *S. pallida* (Singh)
5. Dorsal disc with numerous very short rounded papillae; first abdominal setae absent; vasiform orifice as long as wide ..... *S. cardamomi* (David and Subramaniam)
– Dorsal disc with wavy markings; first abdominal setae present; vasiform orifice wider than long ..... *S. bassiae* (David and Subramaniam)

Depositories and abbreviations

ANIC Australian National Collection, CSIRO Entomology, Canberra, ACT, Australia.

BMNH The Natural History Museum, London, United Kingdom.

IARI The Division of Entomology, Indian Agricultural Research Institute, New Delhi, India.

IWST Institute of Wood Science and Technology, Bangalore, India.

NFICFRI National Forest Insect Collection, Forest Research Institute, Dehra Dun, India.

NMNH National Museum of Natural History, Tel-Aviv University, Israel.

NTU National Taiwan University, Taipei, Taiwan 107, Republic of China.

SMTD Staatliches Museum für Tierkunde, Dresden, Germany.

USDA Systematic Entomology Laboratory, U. S. Department of Agriculture, Beltsville, Maryland, USA.

ZMU Zoological Museum, Universitetsparken, Copenhagen, Denmark.

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REFERENCES

David, B. V. and Subramaniam, T. R. (1976) Studies on some Indian Aleyrodidae. *Records of Zoological Survey of India* **70**: 133–233.

Dubey, A. K. and Sundararaj, R. (2005) A review of the genus *Aleuroclava* Singh (Hemiptera: Aleyrodidae) with description of eight new species from India. *Oriental Insects* **39**: 241–272.

Jensen, A. S, (2001) A cladistic analysis of *Dialeurodes, Massilieurodes* and *Singhiella* with notes and key to the Nearctic species and descriptions of four new *Massilieurodes* species (Hemiptera: Aleyrodidae). *Systematic Entomology* **26**: 279–310.

Jesudasan, R. W. A. and David, B. V. (1990) Revision of two whitefly genera, *Aleuroclava* Singh and *Aleurotuberculatus* Takahashi (Homoptera: Aleyrodidae). *FIPPAT Entomology Series* **2**: 1–13.

Martin, J. H. (1999) The whitefly fauna of Australia (Sternorrhyncha: Aleyrodidae): An taxonomic account and identification guide. *CSIRO Entomology Technical Paper* **38**: 1–97.

Qureshi, J. L. and Qayyam, H. A. (1969) Redescription of the genus *Singhiella* and description of a new species, *Singhiella crenulata* (Homoptera: Aleyrodidae), from Lyallpur. *Pakistan Journal of Zoology* **1**: 177–179.

Sampson, W. W. (1943) A generic synopsis of the Hemipterous Superfamily Aleyrdoidea. *Entomologica America* **23**: 173–223.

Singh, K. (1931) A contribution towards our knowledge of the Aleyrodidae (whiteflies) of India. *Memories of Department of Agriculture India Entomological Search* **12**: 1–98.

Sundararaj, R. and David, B. V. (1993) New species of *Aleuroclava* Singh from India (Homoptera: Aleyrodidae). *Oriental Insects* **27**: 233–270.

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Spodoptera litura (Fabricius) (Lepidoptera: Noctuidae) on custard apple in India

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ABSTRACT: The tobacco caterpillar *Spodoptera litura* (Fabr.) was observed an custard apple *Annona squamosa* Linn causing defoliation of plants at the Indian Institute of Horticultural Research Farm, Bangalore. The larvae of *S. litura* were able to complete development on custard apple leaves under laboratory conditions. This is the first report of *S. litura* occurring on custard apple in India.

KEYWORDS: *Spodoptera litura*, custard apple

About 20 insect pests have been reported on custard apple *Annona squamosa* Linn. in India (Butani, 1976).

In November 2004, eggs and larvae of the tobacco caterpillar *Spodoptera litura* (Fabr.) were observed on the leaves of *A. squamosa*, cultivar *Arka sahan* at Indian Institute of Horticultural Research Farm, Bangalore, Karnataka. The first and second instar caterpillars were found in groups skeletonising the leaves. Late instar caterpillars were found defoliating the plants in the field. The newly hatched larvae from the field-collected eggs were able to complete their development on custard apple leaves in the laboratory. According to Butani (1976) and perusal of literature, there is no record of *S. litura* on custard apple in India.

Field collected eggs and larvae of *S. litura* did not yield any natural enemy in the present investigation, though several natural enemies have been reported on different stages of *S. litura* in different crop ecosystems.

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REFERENCES

Butani, D. K. (1976) Insect pests of fruit crops and their control — Custard apple. *Pesticides* **10**: 27–28.

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Short Communication No. ent.31311

Scales and mealybugs (Coccoidea: Hemiptera) infesting sandal (*Santalum album* Linn.)

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ABSTRACT: A survey on sandal, *Santalum album* Linn. in seedling stage and trees in plantations and natural forests revealed the presence of 23 species of scales and mealybugs. Of these, seven are new records.

KEYWORDS: sandal, coccids

The scale insects and mealybugs (Superfamily Coccoidea: Hemiptera) are commonly referred to as coccids or coccoids (Varshney, 1992). They are most important pests of perennial plants and can cause serious damage to nut and fruit trees, woody ornamentals, forest vegetation, and greenhouse plants. Damage is usually caused by removal of plant sap, and introduction of plant pathogens or, toxins, and the production of large quantities of honeydew with resultant growth of sooty mold fungi that cover leaf surfaces and reduce photosynthesis (Ayyar, 1929).

Coccids infesting sandal (*Santalum album* Linn.) in India were reported by Mathur and Singh (1961); Varshney (1992, 2002). Sandal is an important tree crop in India and nurseries have been established in different states for large-scale plantation programmes. Among more than 150 insects known to occur on sandal the infestation by sucking insects belonging to the family Coccidae is very deleterious as they affect the normal growth and reproduction of sandal plants (Remadevi *et al.*, 2005). In the present study detailed surveys were undertaken in Bangalore, Thangali and Mandagadde in Karnataka, Kavalur and Chitteri in Tamil Nadu and Marayoor in Kerala, to identify the scale and mealybugs infesting sandal.

The study revealed 23 species of scales and mealybugs under 5 families (Table 1). Among these seven species viz.., *Megapulvinaria maxima* (Green), *Fiorinia fioriniae*

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TABLE 1. Scales and Mealybugs infesting sandal

Family	Scientific name	Common name
Coccidae	*Cardiococcus bivalvata* (Green)	Bivalved scale
	Ceroplastes actiniformis Green	Coconut wax scale
	Ceroplastes ceriferus (Fabricius)	The Indian wax scale
	Parasaissetia nigra (Nietner)	Nigra scale/Black bug
	Pulvinaria psidii Maskell	The green shield scale
	Saissetia coffeae (Walker)	Hemispherical scale
	*Megapulvinaria maxima** (Green)	Neem scale
Diaspididae	*Aonidiella orientalis* (Newstead)	Oriental scale
	*Fiorinia fioriniae** Targioni Tozzetti	Fiorinia/Avacado scale
Kerridae	*Paratachardina lobata lobata* (Chamberlin)	Lobate scale/psuedo scale
	Paratachardina silvestrii (Mohdihassan)	The pseudolac scale
Margarodidae	*Icerya aegyptiaca** (Douglas)	Egyptian mealybug
	I. formicarum Newstead	–
	I. purchasi Maskell	Cottony cushion scale
	*I. seychellarum** Westwood	Common white mealy bug
	Hemaspidoproctus cinerus	Giant mealybug
	Perissopneumon phyllanthi (Green)	–
Pseudococcidae	*Ferrisia virgata** (Cockerell)	Striped mealybug
	Nipaecoccus filamentosus (Cockerell)	Spherical mealybug
	*Nipaecoccus viridis** (Newstead)	Coconut mealybug
	*Pseudococcus longispinus** (Targioni Tozzetti)	Long tailed mealybug
	Rastrococcus iceryoides (Green)	Mutabilis mealybug
	Lankacoccus ornatus (Green)	Jasmine mealybug

*New record on sandal

Targioni Tozzetti, *Icerya aegyptiaca* (Douglas), *I. seychellarum* Westwood, *Ferrisia virgata* (Cockerell), *Nipaecoccus viridis* (Newstead) and *Pseudococcus longispinus* (Targioni Tozzetti) are new records on sandal. The infestation of *Cardiococcus bivalvata* (Green), *Parasaissetia nigra* (Nietner), *Saissetia coffeae* (Walker), *Ceroplastes actiniformis* Green, *C. ceriferus* (Fabricius) and *Paratachardina silvestri* (Mohdihassan) often resulted in drying of branches of trees and death of seedlings. The affected flowers wither and fruits dry and fall off prematurely and do not germinate (Sivaramakrishnan *et al.*, 1987). The seedlings and trees are affected severely by *Aonidiella orientalis* (Newstead), *Icerya aegyptiaca* (Douglas), *I. purchasi* Maskell and *Megapulvinaria maxima* (Green), *M. maxima* secrete plenty of honeydew that leads to the development of black sooty mould on the surface of leaves and branches. The remaining coccids seem to be not economically important, as their infestation is of minor nature.

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REFERENCES

Ayyar, T. V. R. (1929) A contribution to our knowledge of south Indian coccids (scales and mealybugs). *Imperial Institute of Agricultural Research Bulletin No.* **197**: 41–43.

Mathur, R. N. and Singh, B. (1961) A list of insect pests of forest plants in India and the adjacent countries. List of insect pests of plant genera 'S' (*Sabia* to *Syzygium*). In: *Indian Forest Bulletin (New Series) Entomology*, Forest Research Institute: Dehra Dun., **No. 171,** (8), Part-9: 1–86.

Remadevi, O. K., Nagaveni, H. C. and Muthukrishnan, R. (2005) Pests and diseases of sandalwood plants in nurseries and their management. *Working Papers of the Finnish Forest Research Institute* **11**: 69–74.

Sivaramakrishnan, V. R., Nagaveni, H. C. and Muthukrishnan, R. (1987) Poor seed-setting on sandal (*Santalum album* L.). *My forest* **23(34)**: 101–103.343–344

Varshney, R. K. (1992) *A checklist of the scale insects and mealybugs of south Asia*, Records of Zoological: Survey of India, Occassional paper No. 139, p. 152

Varshney, R. K. (2002) *A checklist of the scale insects and mealybugs of south Asia (Part-2)*, Records of Zoological: Survey of India, Occassional Paper No. 191, 1–147

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Regulation of haemocytes in the red cotton stainer *Dysdercus similis* Freeman (Heteroptera: Pyrrhocoridae)

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ABSTRACT: The role of haemopoiesis and mitosis in regulation of haemocyte numbers was investigated in *Dysdercus similis*. Total haemocyte counts were higher in nymphs as compared to the adults. The counts varied significantly in various stages of the female adult in comparison to the male. When exposed to stress factors like starvation, freezing temperature and continuous light, significant variations were caused in insects of both the sexes. Mitosis was noticed in Prohaemocytes (PR), Plasmatocytes (PL), Granulocytes (GR), Coagulocytes (CO) and Adipohaemocytes (AD), but it does not appear to play a very significant role in augmenting the numbers of haemocytes. Haemocytoblasts and isogenic cell islets with PR were seen in the third and fifth nymphs.

KEYWORDS: Insect immunity, Haemopoiesis, mitosis, mitotic index

Haemocytes circulating in the haemolymph are known to vary in accordance with the physiological state of the insect as well as in response to a challenge (Shapiro, 1979; Gupta, 1985). Also, insect haemocytes need constant replacement as these cells are said to have a life span varying from 6 to 17 days (Shrivastava and Richards, 1965; Lea, 1986; Lackie, 1988). The role of haemopoiesis and mitosis in circulating as well as sessile haemocytes needs to be examined. The present investigation is aimed at (a) a comparative assessment of haemocytes in various stages of *D. similis* Freeman, (b) assessment of the extent of mitosis in various haemocytes and (c) inducement of mitosis in different haemocytes of *D. similis* subjected to some stress factors.

Life stages of *D. similis* were obtained from a culture maintained in the laboratory on water soaked cotton seeds, at 30 ± 2°C, 70–80 RH and L/D cycles of 14/10 h. The

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FIGURE 1. A haemocytoblast noted in the blood film of fifth instar nymph of *Dysdercus similis*. Giemsa, x400. A number of Prohaemocytes (PR) separating from the cell can be noted.

stages examined were second to fifth instar nymphs, adults of both sexes (<4 h post-ecdysis), males and females during mating, mated females before and after oviposition and senescent stages (>40 days old) of both sexes.

Various haemocyte types were identified by the Hanging drop method of Gupta (1979). Samples of blood films were prepared and stained following the method of Arnold and Hinks (1979). Total Haemocyte counts (THC) were carried out using improved Neubauer haemocytometer, after Kalia *et al.* (2001). All data on THC are a mean of 10 replicates. Mitotic Index (MI) was the number of haemocytes undergoing mitotic division (metaphase and later stages), per 1000 cells observed, in the blood film studied under a microscope. Each MI is a mean of readings from at least three films. Overall Mitotic Index represented the number of dividing haemocytes per 1000 cells, regardless of the cell types. MI within a cell type represented the index within that particular haemocyte type. In order to study the effect of stress on the number of haemocytes and mitosis in these haemocytes, the procedures adopted were (a) starvation, in which only water was provided to otherwise normal insects while insects reared on soaked cotton seeds served as control, (b) exposure to freezing temperature and (c) rearing under continuous light for long duration. In (b) and (c) also insects reared under normal conditions sans the stress, served as controls. For (c), a photoperiodic chamber (Pathak, 2005) was used.

Apart from various haemocytes, a few haemocytoblasts and 'isogenic cell islets' were noted in the haemolymph of third and fifth nymphs of *D. similis* (Figures 1, 2). New PR were seen arising from the haemocytoblasts and released into the haemolymph. Haemocytoblasts and isogenic cell islets had earlier been reported from the vicinity of the haemopoietic organ (HPO) in *Locusta* (Hoffmann, 1970), in which the newly formed PR were being released into the pericardial sinus only after differentiation. It is for the first time that haemocytoblasts and isogenic cell islets were noted circulating in the haemolymph.

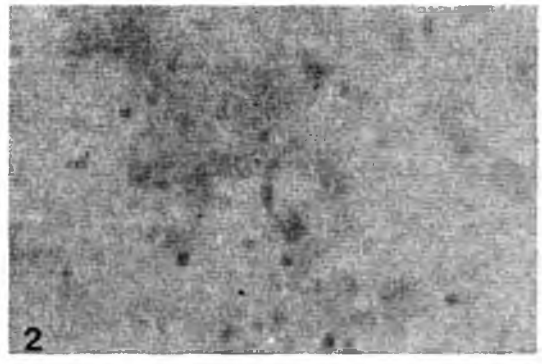

FIGURE 2. An isogenic cell islet seen in the blood film of the fifth instar nymph of *Dysdercus similis*. Giemsa, x400.

Variation was notable in the number of free haemocytes in various stages of *D. similis* as was the case in *Blattella germanica* (Pathak and Kulshrestha, 1993; Pathak *et al.*, 1995). Tables 1 and 2 present the number of free haemocytes in the nymphs and adults from premature to senescent. Among the nymphs, fourth instar had the highest number followed very closely by the fifth. Among the adults the number rises to almost double in the 'females after mating but before oviposition' and then plummets down to incredibly small number after oviposition. It appears that the stage is extremely vulnerable but recovers soon, the THC reaching the normal level. The number is generally low in the senescent stages but is higher in the female. Unlike what is noted in *D. similis*, Jones had noted the highest number of free haemocytes in the fifth nymphs of *Rhodnius*, but it is generally acknowledged that the number is higher in the larval stages in comparison to adults (Shapiro, 1979; Gupta, 1985).

Exposure to conditions of stress like starvation, freezing temperature and continuous light led to changes in THC. Starvation for 36 h or more, appeared to block the normal increase. Earlier Steinhaus (1958) and Steinhaus and Dineen (1960) had stated that conditions of stress adversely affected the immuno-competency of an insect. But Richards and Edwards (1999) have found that starvation does not affect the haemocyte number in the tomato moth *Locanobia oleracea* parasitized by the ecto-parasitic wasp *Eulophus*. Exposure to freezing temperature led to some statistically significant increase in THC within 2 h. Continuous light seemed to affect males differently than the females, the counts being low after 24 h of exposure while the same in the females was almost unchanged.

It appeared that in *Dysdercus*, the rise in number of haemocytes by haemopoiesis in various stages was brought about both by formation of new haemocytes as well as by mitosis; and the two processes appeared to run simultaneously. Mitosis in various haemocyte types has been reported by a number of authors (see Gupta, 1985; Lackie, 1988). Changes in haemocyte numbers were statistically significant in nymphs (Table 1) and adult females (Table 2) but non-significant in adult males (Table 2).

TABLE 1. Mean total haemocyte count per mm^3, circulating in the haemolymph of second to fifth nymphs of *D. similis*

Nymph stage	Total haemocyte count ± S.D.
Second	33020 ± 2025
Third	14646 ± 377
Fourth	57340 ± 5151
Fifth	55877 ± 1220
C.D	133.2*

*Significant

TABLE 2. Mean total haemocyte count per mm^3, circulating in the haemolymph of adult *Dysdercus similis*

Stage	Total haemocyte count ± S.D.	
	Male	Female
Freshly moulted	20588 ± 937	33308 ± 2800
Mature adult (>4 days old)	14150 ± 655	28382 ± 410
During mating	17000 ± 2068	27386 ± 9240
After mating/after mating but before oviposition	16576 ± 246	52313 ± 5497
Mated, after oviposition	–	6220 ± 1157
Senescent, (>40 days old)	10292 ± 1576	13520 ± 2037
C.D.	3.17^{NS}	10.7*

NS: Non-significant *Significant

When these numbers were viewed in adults subjected to various stress factors, it was noted that the changes in males subjected to starvation were non-significant whereas they were statistically significant in females treated similarly. Changes in THC in insects exposed to freezing temperature were significant in both the sexes and the same was the case in insects in which the light/dark cycle had been drastically altered (Table 3).

Tables 4 and 5 present the extent of mitosis occurring in various haemocytes of *Dysdercus*. It has been noted that variation in mitotic index were significant in overall MI, but the changes in PR, PL, GR, CO and AD individually were not significant in case of insects reared under normal conditions. The results were similarly non-significant in case of not only PR, PL and even GR but also over all MI in insects of both sexes exposed to starvation and continuous light, although some increase was noted in PL in starved male and in both PR and PL in starved female. Thus, the role of mitosis in replacing haemocytes appears to be lesser than the formation of new ones by haemopoiesis.

TABLE 3. Mean total haemocyte count per mm^3, circulating in the haemolymph of adult *D. similis* exposed to stress factors

Type of stress	Exposure time (h)	THC per $mm^3 \pm$ S.D. Male	Female
Starvation	12	14786 ± 2437	26001 ± 1731
	24	14265 ± 3345	21976 ± 897
	36	13123 ± 132	18659 ± 934
	48	10744 ± 753	17182 ± 1719
	C.D.	1.16^{NS}	24.81*
Freezing temperature	1	15669 ± 508	21526 ± 1857
	3	21430 ± 1418	11890 ± 304
	C.D.	0.47*	0.23*
Continuous light	24	23448 ± 2832	22860 ± 2587
	48	20108 ± 1520	21668 ± 1183
	72	18695 ± 449	24266 ± 842
	96	14905 ± 621	22000 ± 1271
	C.D	18.74*	22.34*

NS: Non-significant, *Significant

TABLE 4. Mitosis in various haemocytes of *D. similis*

Stage of *D. similis*	Overall mitotic index (MI)	Mitotic Index (MI) in each cell type PR	PL	GR	CO	AD
Second nymph	1	0	1.67	0	0	0
Third nymph	1	1.67	0	0	0	0
Fourth nymph	2	0	1.67	0	1.67	0
Fifth nymph	15	8.33	16.66	0	0	0
Male > 4 days old	2	1.67	1.67	0	0	0
Male — Senescent > 40 days old	3	1.67	3.33	0	0	0
Female	1	0	0	0	1.67	0
Female — mated, pre-oviposition	6	1.67	3.33	1.67	0	3.33
Female — Senescent > 40 days old	7	0	11.66	0	0	0
C.D.	6.9*	0	0.2^{NS}	0	0.13^{NS}	0

PR : Prohaemocytes; PL: Plasmatocytes; GR: Granulocytes; CO: Coagulocytes; AD: Adipohaemocytes,
*Significant; NS: Non-significant.

TABLE 5. Mitosis in haemocytes of *D. similis* exposed to starvation and continuous light (abbreviations as in Table 4)

Stage of the insect	Time of exposure (h)	Overall Mitotic index	Mitotic index within cell types		
			PR	PL	GR
A. Starvation					
Males provided only water	12	3	1.67	3.33	0
do	24	2	0	3.33	0
Males fed on soaked cotton seeds (Control)	24	2	1.67	1.67	0
	C.D.	2^{NS}	0.13^{NS}	6.32^{NS}	0
Females provided only water	12	4	3.33	3.33	0
do	24	1	1.67	0	0
do	36	2	3.33	0	0
do	48	1	0	1.67	0
Females fed on soaked cotton seeds (Control)	48	1	1.67	0	0
	C.D.	1.16^{NS}	1^{NS}	0.13^{NS}	0
B. Continuous light					
Males exposed to continuous light	24	1	0	1.67	0
do	72	1	0	0	1.67
Males reared on normal L/D cycle (14L/10D) (Control)	72	2	1.67	1.67	0
	C.D.	1.176^{NS}	0	0.13^{NS}	0
Females exposed to continuous light	24	4	6.66	0	0
do	48	1	0	1.67	0
Females exposed to normal L/D cycle 14L/10D (Control)	48	1	1.67	0	0
	C.D.	1.176^{NS}	0.012^{NS}	0	0

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REFERENCES

Arnold, J. W. and Hinks, C. F. (1979) Insect haemocytes under light microscopy: techniques. In: *Insect Haemocytes*, Gupta, A. P. (Ed). Cambridge University Press: Cambridge, 531–538.

Gupta, A. P. (1979) Identification key for haemocyte types in hanging drop preparation. In: *Insect Haemocytes*, Gupta, A. P. (Ed). Cambridge University Press: Cambridge, 527–529.

Gupta, A. P. (1985) Cellular elements in the haemolymph. In: *Comprehensive Insect Physiology, Biochemistry and Pharmacology*, Kerkut, G. A. and Gilbart, L. I. (Eds). Pergamon Press: NY, **vol. 3**: 401–451.

Hoffmann, J. A. (1970) Les organs hematopoietiques de deux Orthopteres: *Gryllus bimaculatus* et *Locusta migratoria*. *Z. Zellforsch. Mikrosk. Anat* **106**: 451–472.

Kalia, V., Chaudhari, S. and Gujar, G. T. (2001) Changes in haemolymph constituents of American Bollworm, Helicoverpa armigera (Hubner), infected with nucleopolyhedrovirus. *Indian Journal of experimental Biology*. **39**: 1123–1129.

Lackie, A.M. (1988) Haemocyte behaviour. *Advances in Insect Physiology* **21**: 85–178.

Lea, M. S. (1986) A *Sericesthis* iridescent virus infection of the haemocytes of the wax moth *Galleria mellonella*: effects on total and differential counts and hemocyte Ontogeny. *Journal of Invertebrate Pathology* **48**: 42–51.

Pathak, S. C. (2005) Design of a simple and inexpensive photoperiodic chamber. *Vislesan (Journal of Science, R D Univ. Jabalpur)* **9(2)**: 9–10.

Pathak, S. C. and Kulshrestha, V. (1993) Variations in Haemocyte types with reference to reproductive activity in *Blattella germanica* and occurrence of some undescribed haemocyte types in some adult stages. *Entomon* **18**: 199–225.

Pathak, S. C., Kulshrestha, V. and Hazarika, L. K. (1995) Changes in haemocyte counts during various reproductive stages of *Blattella germanica* (L.). *Ind. J. Comp. Anim. Physiol.* **13**: 51–55.

Richards, E. H. and Edwards, J. P. (1999) Effects of parasitization, venom and starvation on host haemocytes. *J. Insect Physiol.* **45(12)**: 1073–1083.

Shapiro, M. (1979) Changes in haemocyte populations. In: *Insect Haemocytes*, Gupta, A. P. (Ed). Cambridge University Press: Cambridge, 476–523.

Shrivastava, S. C. and Richards, A. G. (1965) An autoradiographic study of the relation between haemocytes and connective tissue in the wax moth *Galleria mellonella* L. *Biological Bulletin, Woods Hole* **128**: 337–345.

Steinhaus, E. A. (1958) Stress as a factor in insect disease. *Proceedings of the IXth International Congress of Entomology* **4**: 725–730.

Steinhaus, E. A. and Dineen, J. P. (1960) Observations on the role of stress in a *granulosis* virus of the variegated cutworm. *Journal of Insect Physiology* **2**: 55–59.

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